# Passive solar energy: A masonry wall simulation for Windsor, Ontario.

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# PASSIVE SOLAR ENERGY
# A MASONRY WALL SIMULATION
# FOR WINDSOR, ONTARIO

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To

my wife Margaret

and

daughters,Cynthia and Niza.

## ABSTRACT

"Pasole' is a computer simulation program for passive solar energy. It can simulate a Trombe wall or a Waterwall by thermal network analysis. In its original form as set up at the University of Windsor there was no allowance for modification of Water wall and Trombe wall parameters nor could the program accept weather data in the standard 'TRY' weather tape format.

In this project modifications were made to allow all relevant variables for Trombe wall or Water wall simulation to be input by the user. Additions were made to the program so that it can access, process and use weather data from weather tapes. The weather tapes are for selected Canadian and U.S.A. cities for a selected year (Test Reference Year. 'TRY'). A user's manual was written on how to run the program at the University of Windsor.

Using the modified program, a computer simulation of the Trombe wall passive solar system, was carried out for Windsor, Ontario, using Detroit, Michigan weather tape.

The optimum Trombe wall thickness was determined to be 10 inches. The optimum type of window was double glazing. Using the prices of materials in Windsor in September 1981 and economic variables for the Fall 1981, the payback period for the 10 inch double glazed Trombe wall, with an area equal to 15% of the floor area, was 22 years.

The program was also used to estimate the solar contri-

bution to the building heating demand of the Trombe wall in the Solar Cottage built by N.K. Becker in Wheatley, Ontario. The payback period for the Trombe wall system in this cottage was estimated to be 39 years.

A comparison of solar contribution to building heating for three Ontario cities, Windsor, Toronto and Ottawa showed that a Trombe wall in Toronto and Ottawa had a better thermal performance than in Windsor.

The results established the thermal advantage of utilizing a Trombe wall in Windsor area. The choice of incorporating the system in a building was shown to depend mainly on economics.

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# CHAPTER I

## INTRODUCTION

Passive solar heating is defined as the heating of a building in which the solar energy is collected and distributed by natural means, such as conduction and convection. All components are deliberately sized and located to facilitate natural energy transfer.

A passive solar heating system can either be

(i) a direct gain system

or (ii) an indirect gain system.

Among the indirect gain systems is the masonry wall system, commonly known as the Trombe wall. Shown in Fig 1.1.

In a Trombe wall passive solar system the solar radiation strikes the masonry wall which is positioned directly behind the south facing glazing. The solar energy is then distributed to the room by convection through the vents provided in the wall and by conduction through the masonry wall. The convection normally occurs during the daylight hours. The solar energy conducted through the masonry wall reaches the room at night. Flaps over the top vents stop reverse convection of warm room air to the cold space between the wall and the glazing at night or on cold cloudy days. Shutters are used on the outside to reduce heat loss to the outside at night and on cold cloudy days.

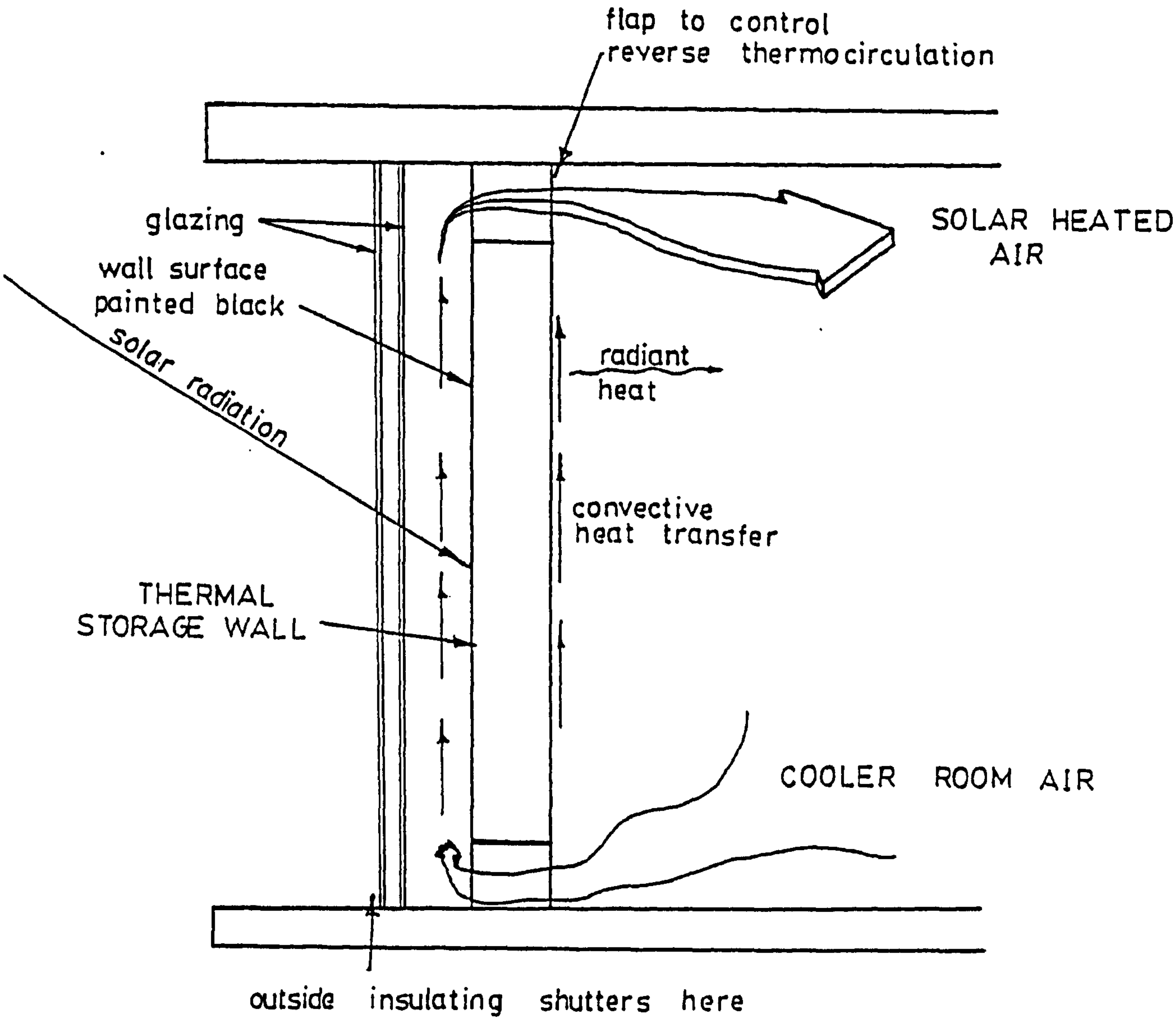


FIG 1·1 Trombewall Passive Solar Heating System.

This project analyses,by computer simulation, the performance of the Trombe wall system in Windsor area.

The importance of this project is that it provides for Windsor, Ontario the data required to make a decision on whether or not to incorporate the Trombe wall passive solar system into a house.

To analyse the performance of the masonry wall passive solar heating system over a whole heating season, a computer simulation was used. In this project the simulation was done by use of a computer program called "Pasole". This is a general passive solar energy computer program that simulates a masonry wall and a waterwall. It calculates hour by hour results utilizing weather data for a selected test reference year (TRY)*. The program calculated for a masonry wall passive solar heating system, the net amount of solar energy contribution to the building heating.

Before using Pasole, modifications and additions had to be made so that it could access and use data from weather tapes. The program as it exists at the University of Windsor computer centre is subsequently referred to as Pasole 2.

The economics of adding the masonry wall passive solar heating system are also analysed for Windsor, Ontario. The prices used in the analysis were for September 1981.

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*TRY= Test Reference Year Data Available for a number of cities from National Weather Bureau. Ashville N.C.

# CHAPTER II

## LITERATURE SURVEY

Passive solar energy can contribute a sizeable amount to the heating requirements of buildings. Such buildings must have their windows located south east to south west through south. Sizing these windows for most efficient use of solar energy is determined by various factors. Some of these factors are:

a) the percentage of total heating the solar energy has to contribute.

b) available thermal storage mass in the building enclosure. (1)

c) the passive solar system chosen, (1) (2)

d) location and climatic conditions. (1) (2)

e) other auxiliary control systems available for limiting indoor temperature fluctuations. e.g. night insulating shutters or blinds and window overhangs. (1) (2)

Mazria[2] lays out rules of thumb which can be used to determine the initial size of the south facing glazing for the various passive solar heating systems.

The sizes for masonry wall, waterwall and direct gain glazing are tabulated in Tables 2.1 (a) (b) and (c) respectively. The passive solar energy system area is

TABLE 2.1 (A). Preliminary size of masonry wall area as a fraction of heated floor area.

| Average Winter (Clear-day) Outdoor Temperature | Masonry wall area/Space floor area.[1] | | | |
| --- | --- | --- | --- | --- |
| | 36°NL | 40°NL | 44°NL | 48°NL |
| Cold Climates | | | | |
| 20°F | .71 | .75 | .85 | .95 |
| 25°F | .59 | .63 | .75 | .84 |
| 30°F | .50 | .53 | .60 | .70 |
| Temperate Climates | | | | |
| 35°F | .40 | .43 | .50 | .55 |
| 40°F | .32 | .35 | .40 | .44 |
| 45°F | .25 | .26 | .30 | .33 |

These tables apply to a well insulated space with a heat loss of 8 BTU/day/sq.ft.$_{fl.}$/°F. If space heat loss is more or less than this figure, adjust the ratios accordingly. The surface area of the wall is assumed to be the same size as the glazing.

TABLE 2.1 (B). Preliminary size of water wall as a fraction of heated floor area.

| Average Winter (Clear-day) Outdoor Temperature | Water wall area/Space floor area. | | | |
| --- | --- | --- | --- | --- |
| | 36°NL | 40°NL | 44°NL | 48°NL |
| Cold Climates | | | | |
| 20°F | .52 | .55 | .65 | .80 |
| 25°F | .45 | .47 | .55 | .64 |
| 30°F | .36 | .39 | .45 | .55 |
| Temperate Climates | | | | |
| 35°F | .28 | .31 | .35 | .40 |
| 40°F | .23 | .25 | .29 | .32 |
| 45°F | .17 | .18 | .20 | .24 |

Note: [1]For thermal walls with a horizontal specular reflector equal to the height of the wall in length, use 67% of the recommended ratios. For thermal walls with night insulation (R-8), use 85% of the recommended ratios. With both night insulation and reflectors, use 57% of the recommended ratios.

Table 2.1(A), from, 'A Design and Sizing procedure for passive solar heated building'. E. Mazria. Report Sand 79-0824 pp. 229, 242. Passive Solar Buildings.

TABLE 2.1 (C). Preliminary size of Direct gain windows as a fraction of heated floor area. (double glazing).

DIRECT GAIN

| Average Winter (Clear-day) Outdoor Temperature[1] | Glazing/Floor area[2] 36°NL | 40°NL | 44°NL | 48°NL | |
|---|---|---|---|---|---|
| Cold Climates | | | | | |
| 20°F | .24 | .25 | .29 | .31 | (w/night insul.) |
| 25°F | .22 | .23 | .25 | .28 | (w/night insul.) |
| 30°F | .19 | .20 | .22 | .24 | |
| Temperate Climates | | | | | |
| 30°F | .16 | .17 | .19 | .21 | |
| 40°F | .13 | .14 | .16 | .13 | |
| 45°F | .10 | .11 | .12 | .13 | |

Notes: [1]Temperatures listed are for December and January, usually the coldest months.

[2]These ratios apply to a well insulated space with a heat loss of 8 BTU/day/sq. $Ft._{fl}$/°F. If space heat loss is more or less than this figure, adjust the ratios accordingly.

given as a fraction of the heated floor area. The tables were made from data on existing solar houses. The sizes are given as a function of latitude and winter outdoor average temperature.

For the Southern United States it has been shown by Arumi and Hourmanesh [3] in Texas and Balcombe [4] in Los Alamos that the optimum thickness of the wall, in the Trombe wall passive solar system, is 12 inches. Increasing the wall thickness above 12 inches does not result in substantial increase in solar energy used to heat the buillding.

Table 2.2 [1] is a compilation of data on some existing passive solar heated houses which make use of the masonry wall passive soalar heating system. Some of the houses have other passive solar heating systems in addition to the masonry wall. These are called mixed systems. The amount of south-facing glazing and the percentage of solar heating achieved are tabulated. The south-facing glazing area in these buildings ranges from six percent to 142 percent of the heated floor area. The heating percentage contributed by solar energy also varies accordingly. The percentage of solar energy contribution is determined mainly by (i) internal thermal storage in the building envelope, (ii) use of night insulating shutters on windows, (iii) insulating level in the rest of the building.

Table 2.2

Amount of South Glazing in Various solar houses and the percentage solar energy contribution of seasonal heating.

| | House | Degree Days (DDF) | Heated Floor Area $ft^2$ | South Window Area | % of Floor = South Window | Solar Energy Contribution |
|---|---|---|---|---|---|---|
| 1. | Delap House Fayetterville AR. $36^oN$ (1976) Hybrid | 3800 | 2000 | 860 $ft^2$ | 43% | 60-75% |
| 2. | Community Environment Santa Barbara C.A. $32^oN$ | 1507 | 2200 | 370 $ft^2$ | 16.8% | 70% |
| 3. | Lasar House $41^oN$ | 5897 | 2460 | 500 $ft^2$ 375 $ft^2$ vert 125 $ft^2$-$60^o$ Greenhouse | 20% | 65% no shutters 80% with shutters R-10. |
| 4. | Tyrrel House Bedford N.H. $43^oN$ | 7643 | 1920 | 300 $ft^2$ Trombe + 150 $ft^2$ Drain | 23.43% | 60% |
| 5. | Reckard House Northwood N.H. $43^oN$ | 7383 | 2500 | - | - | 40-60% |
| 6. | Klein House Bally P.A. $40.5^oN$ | 5250 | 400 | 570 $ft^2$ | 142.5% | 100% |

Source Reference ( 1 ).

Bruno[5] showed that in houses with low insulation levels, an increase in direct gain south-facing window area resulted in a decrease in the building heating demand. As the insulation increased, however, this advantage is lost and for heavily insulated buildings an increase in window area resulted in an increase in the building heating demand. This study was done for Hamburg, Germany. Fig. 2.1 shows these results.

The maximum and minimum allowed indoor temperature influences the amount of solar energy used to heat the building. The lower the temperature is allowed to drop in the building before turning on auxiliary heat, the more solar energy will be used. Also the higher the temperature is allowed to go before turning on the cooling or opening the windows to let the excess heat out, results in an increase in the amount of solar energy used. This is because the energy storage in the building is increased (1) (6 ).

Table 2.3 is a compilation of data simulated on Pasole by Balcombe et al.[4] The results show the solar energy contribution to building heating for 29 different climates. The simulations are for an 18 inch thick Trombe wall.

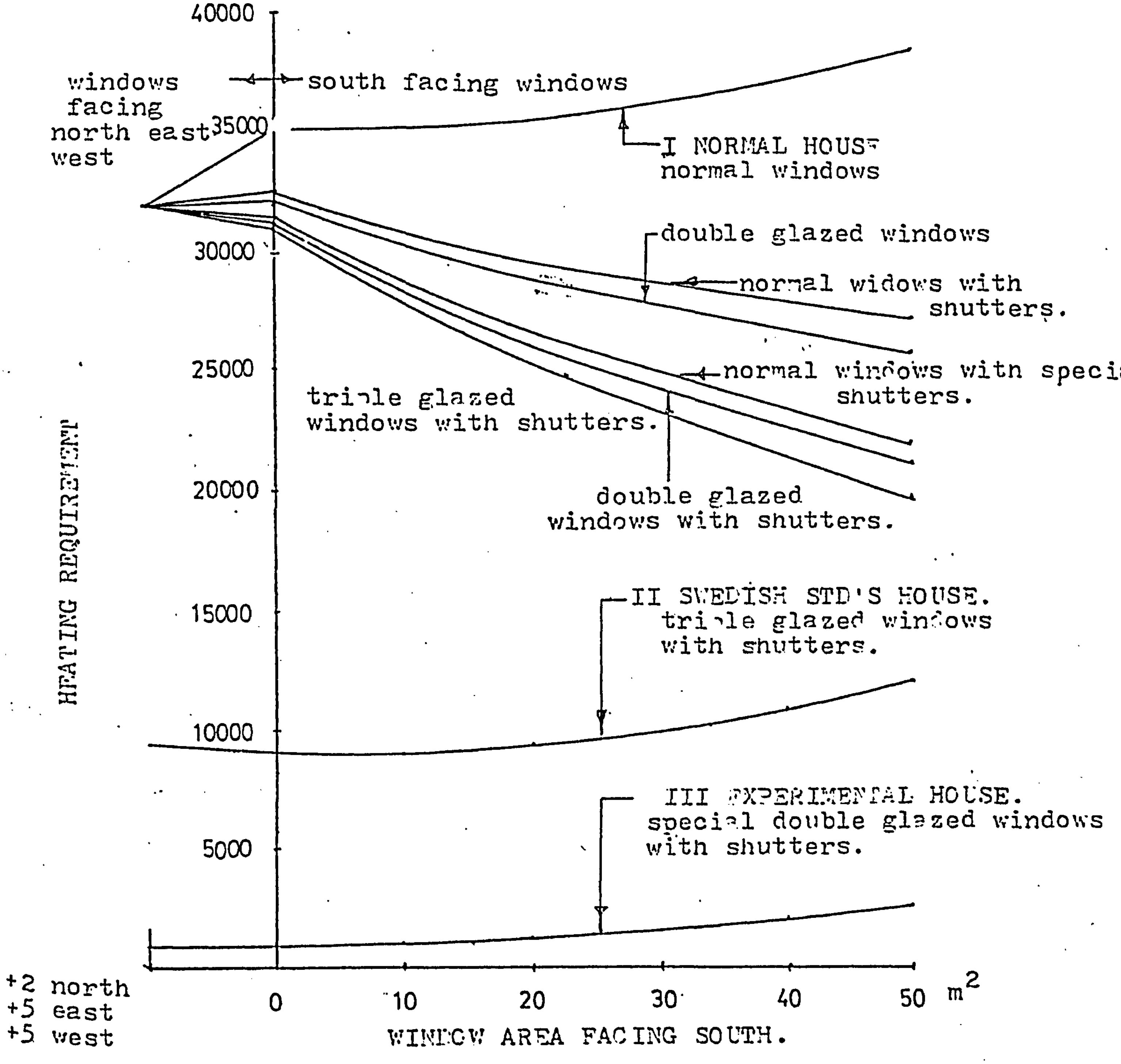



FIG 2.1 Heating requirements as a function of the window area. (Hamburg, 1973). Reproduced from Bruno(5).

## TABLE 2·3

## ANNUAL SOLAR HEATING RESULTS FOR 29 VARIOUS CLIMATES

**Case:** 18 in. Trombe Wall
Thermal Conductivity = 1 BTU/ft hr °F
Heat Capacity = 30 BTU/$ft^3$ °F
Vent Size = 0.074 $ft^2$/ft of length (each vent)
No reverse thermocirculation
Load ($U_1$) = 0.5 BTU/$ft^2$ °F hr
Temperature band = 65°F to 75°F

| City | Year Starting | Heating Degree-Days | Latitude | Solar Heating,* BTU/$ft^2_g$ | Solar Heating Fraction, Percent |
|---|---|---|---|---|---|
| Los Alamos, NM | 9/1/72 | 7350 | 35.8 | 60,200 | 56.5 |
| El Paso, TX | 7/1/54 | 2496 | 31.8 | 50,000 | 97.5 |
| Ft. Worth, TX | 7/1/60 | 2467 | 32.8 | 38,200 | 80.8 |
| Madison, WI | 7/1/61 | 7838 | 43.0 | 44,900 | 41.6 |
| Albuquerque, NM | 7/1/62 | 4253 | 35.0 | 63,600 | 84.1 |
| Phoenix, AZ | 7/1/62 | 1278 | 35.5 | 38,300 | 99.0 |
| Lake Charles, LA | 7/1/57 | 1694 | 30.1 | 34,300 | 90.5 |
| Fresno, CA | 7/1/57 | 2622 | 36.8 | 43,200 | 83.3 |
| Medford, OR | 7/1/61 | 5275 | 42.3 | 47,400 | 56.1 |
| Bismarck, ND | 7/1/54 | 8238 | 46.8 | 53,900 | 46.4 |
| New York, NY | 6/1/58 | 5254 | 40.6 | 48,000 | 60.2 |
| Tallahassee, FL | 7/1/59 | 1788 | 30.3 | 40,700 | 97.3 |
| Dodge City, KS | 7/1/55 | 5199 | 37.8 | 58,900 | 71.8 |
| Nashville, TN | 7/1/55 | 3805 | 36.1 | 39,500 | 65.2 |
| Santa Maria, CA | 7/1/56 | 3065 | 34.8 | 69,800 | 97.9 |
| Boston, MA | 7/1/57 | 5535 | 42.3 | 47,100 | 56.8 |
| Charleston, SC | 7/1/63 | 2279 | 32.8 | 47,900 | 89.3 |
| Los Angeles, CA | 7/1/63 | 1700 | 34.0 | 53,700 | 99.9 |
| Seattle, WA | 7/1/63 | 5204 | 47.5 | 42,400 | 52.2 |
| Lincoln, NE | 7/1/58 | 5995 | 40.8 | 53,500 | 59.1 |
| Boulder, CO | 1/1/56 | 5671 | 40.0 | 62,500 | 70.0 |
| Vancouver, BC | 1/1/70 | 5904 | 49.1 | 46,000 | 52.7 |
| Edmonton, ALB | 1/1/70 | 11679 | 53.5 | 37,700 | 24.7 |
| Winnipeg, Man | 1/1/70 | 11490 | 49.8 | 33,700 | 22.6 |
| Ottawa, Ont. | 1/1/70 | 8838 | 45.3 | 37,900 | 31.9 |
| Fredericton, NB | 1/1/70 | 8834 | 45.8 | 40,100 | 33.9 |
| Hamburg, Germany | 1/1/73 | 6512 | 53.2 | 24,900 | 27.5 |
| Denmark | ? | 6843 | 56 | 43,100 | 43.8 |
| Tokyo, Japan | ? | 3287 | 34.6 | 50,300 | 85.8 |

*The values in the solar heating column are the net energy flow through the inner face of the wall into the building.

From Passive Solar Heating, by Balcombe et al[4]

# CHAPTER III

## "PASOLE"' THE COMPUTER PROGRAM

In order to study the thermal advantage of utilizing the masonry wall passive solar heating system in the Windsor area, the program Pasole was used.

### 3.1 BRIEF DESCRIPTION OF PASOLE

Pasole is a general simulation computer program for passive solar heating. It has incorporated in it, a masonry wall and a waterwall model. The masonry wall is shown in Fig. 3-1. The model breaks the passive solar heating system into a number of nodes with connecting resistances and associated heat capacitance.

#### 3.1.1. DESCRIPTION OF MASONRY WALL MODEL:

The solar energy is absorbed in the surface node No.1 of the masonry wall. From this node the energy is distributed in various proportions to the other connected nodes. The nodes representing the glazing also absorb a portion of the incident solar energy and are also termed source nodes. Some of the solar energy absorbed by the glazing is transmitted into the space.

The finite difference method is used to calculate the heat storage in the masonry wall as well as the heat flow through the masonry wall and the resulting node temperatures.

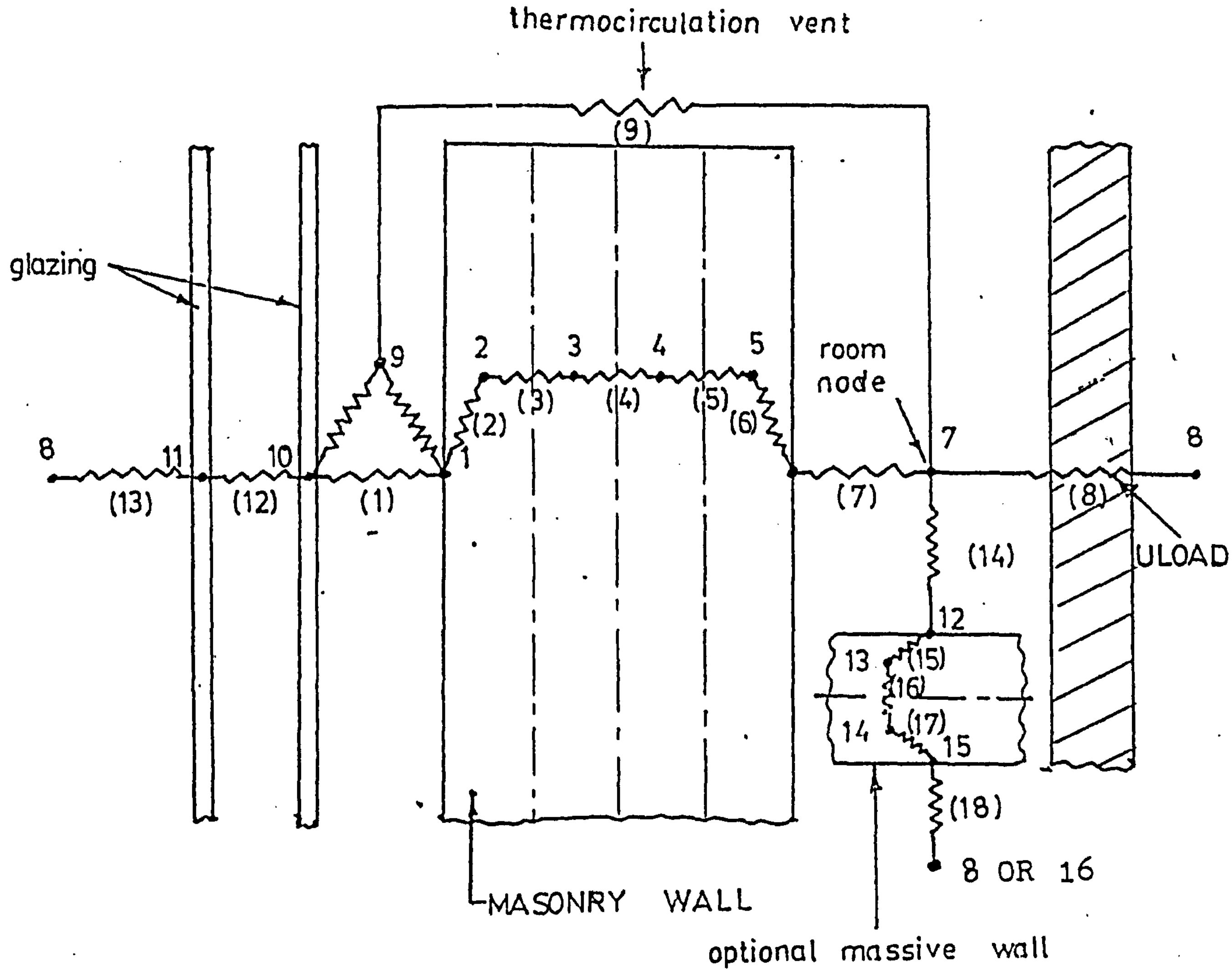



FIG 3.1 Pasole simulation model with optional massive exterior wall. The room node is node 7. The outside is node 8.

As a simplification the loss from the rest of the building is lumped together and represented by one conductance called ULOAD. This is the conductance of the rest of the building per unit south facing glazing area. This assumption neglects the heat storage in the rest of the building. There exists an option to set this conductance to a fraction of the loss from the rest of the building. The rest of the loss is modelled through a massive optional masonry wall which has thermal storage capacity.

Once calculations are completed, the results are available through various print options, hourly, daily, and monthly. A day on which hourly data is required to be printed can be selected. A monthly summary consisting of the sums of the hourly values is given at the end of the calculation. Totals for the simulated period are also given. Several other tables are also printed as shown in Appendix B. The variables in the tables are explained in detail in Appendix B , which contains a complete manual explaining the program Pasole, and all its associated variables. Included in Appendix B is the listing of the program(Pasole) as it exists at the University of Windsor Computer Centre.

## 3.2 MODIFICATIONS TO PASOLE

Since Pasole as originally set up at the University of Windsor Computer Centre cannot accept weather data in the standard TRY tape format, and does not have allowance for modifying variables in the program, it was found necessary to modify Pasole to make it more user oriented. The modified program has subsequently been called Pasole2

The following modifications and additions were made to Pasole:

(a) The program was made 'user oriented' This means that all important variables in masonry wall and waterwall passive solar heating models can now be supplied (on cards) by the user.

(b) For the user at the University of Windsor, the program has been expanded so that it can access TRY data directly and transform it into acceptable format to be used by the program. This is done for U.S.A. cities via ESP [7] weather program. For Canadian cities the weather is accessed and processed by portions from the program ENCORE CANADA [8]. The weather must, however, be on disk files in the computer centre. At present only Detroit, Toronto and Ottawa are on disk files. Tapes for other cities are available.

(c) The loss path through the optional massive masonry outside wall was adjusted so that it can accept a fixed temperature node on the outside. The value of this temperature has to be less than 200°F. This could be used to represent adjacent

rooms which are set at a fixed temperature.
For the node to be set at outdoor temperature, the temperature value must be greater than 200°F. See Appendix B.

(d) At the end of the calculations the net solar energy contribution per month is output. This value has to be modified if the optional wall is used. This modification is necessary only if the optional wall outside temperature is set at a fixed value below 200°F. Then it is necessary to add manually the loss through ULOAD connection and through the extra massive wall.

Appendix B includes a complete manual on how to run Pasole 2. If any problems are encountered consultation with the computer centre consultants is recommended.

# CHAPTER IV

## SIMULATION

The program Pasole 2 was used to simulate a Trombe wall passive solar heating system. The Trombe wall system is shown in Fig. .1. The weather data used in the simulation was for Detroit Michigan, for the year 1968. This weather is supplied as Test Reference Year data from the National Weather Bureau, Ashville N.C. The proximity of Detroit to Windsor makes this data valid for use in Windsor. Comparison was made of average January clear day total observed in Windsor 1971-1978 [9] with the TRY weather for 25th January 1968 and was found to be in agreement within 2%.It was concluded that the use of the Detroit weather was acceptable.

Hour by hour simulations were done for the heating season months. (October to April inclusive). Monthly totals of net solar energy contributed to heating the buildings were calculated and were plotted.

### 4.1 CONDITIONS CONSIDERED IN THE SIMULATION

The following conditions were considered in the simulation:

(a) For an 18 inch Trombe wall (used in Los Alamos Simulation by Balcombe [4]) the net solar energy contribution for single, double and triple glazing was calculated, and plotted, for the heating season,

(b) Varying the masonry wall thickness from 4 inches to 18 inches for a double glazed Trombewall system.

(c) For an 18 inch wall, varying the vent sizes from zero to 25% of the masonry wall area.

(d) For the optimum wall thickness and vent size, varying the indoor temperature float range. The ranges analysed were $65^{o}F/75^{o}F$, $68^{o}F/78^{o}F$ and $70^{o}F$ fixed temperature.

(e) Varying the resistance of night insulating shutters for a double glazed Trombe wall system.

(f) Varying the insulation level in the rest of the building for a double glazed Trombewall system.

(g) The effect on the heating demand of varying the size of the south facing masonry wall area.

# CHAPTER V.

# RESULTS AND OBSERVATIONS

## 5.1 SOLAR HEATING FOR SINGLE, DOUBLE AND TRIPLE GLAZED MASONRY WALL SYSTEM.

Fig. 5.1. shows the amount of net solar energy contribution per foot squared south facing masonry wall area. The results are for single, double and triple glazing. The wall thickness is 18 inches and there are no night insulating shutters. Single glazing has net heat losses to the outdoors in three of the heating season months. Double glazing has net positive solar energy contribution in all the months except in December. Triple glazing has positive solar energy contribution in all the heating season months. The advantage of changing from double to triple glazing is small compared to the change from single to double glazing.

The negative values in the single and double glazing mean that the solar energy collected during the month was less than the amount of heat conducted to the outdoors through the same window.

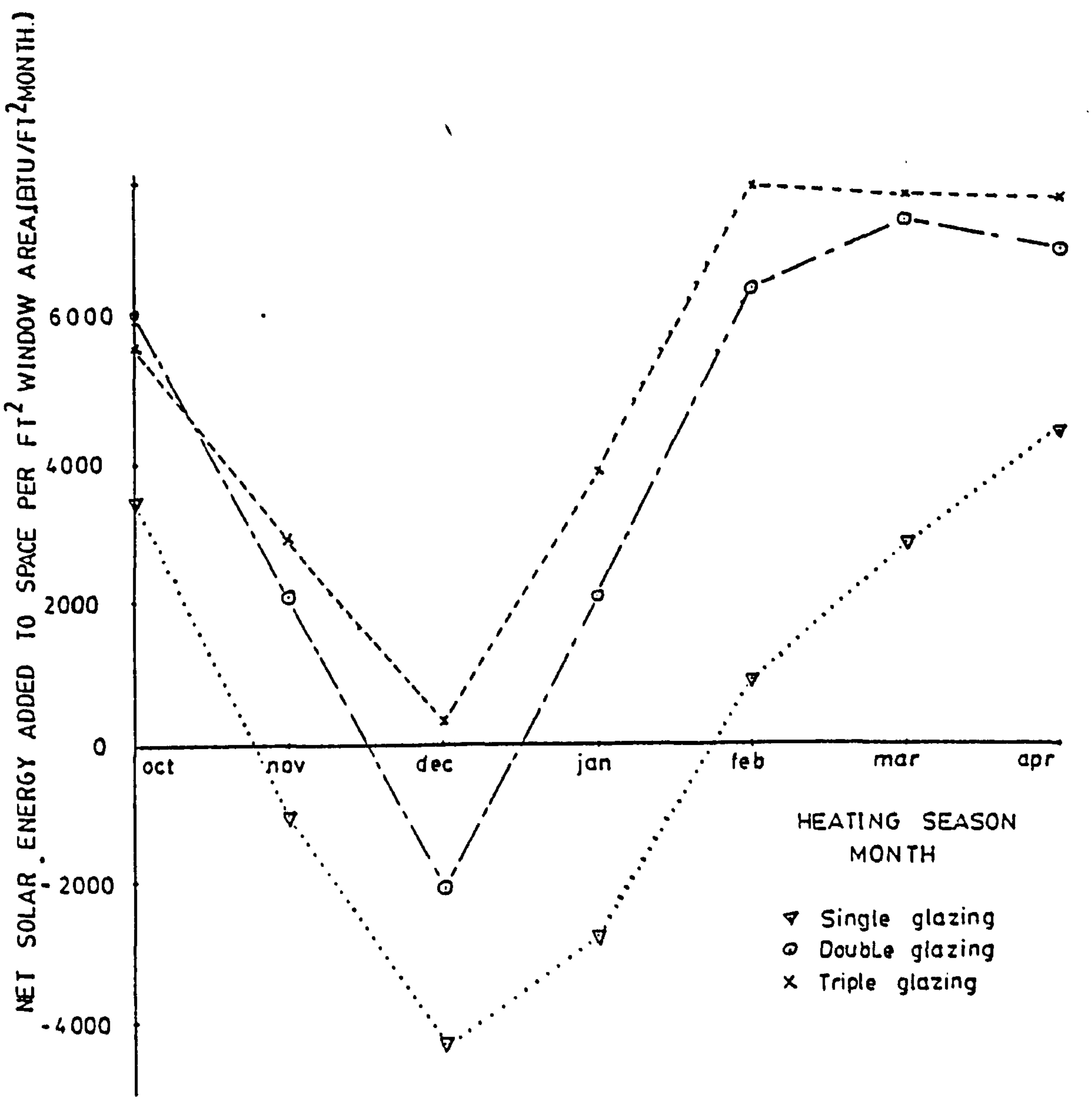



FIG 5.1 Monthly solar energy contribution to building heating per $ft^2$ Trombe wall area. Indoor temperature setting $T_{max}$=78 F. $T_{min}$=68 F. Wall thickness= 18 inches. Average insulated building. ULCAD= 1.2.

## 5.2 NET SOLAR ENERGY CONTRIBUTION AS AFUNCTION OF MASONRY WALL THICKNESS FOR A DOUBLE GLAZED WINDOW.

Fig 5.2 shows the effect of varying the masonry wall thickness for a double glazed window with an indoor temperature float range of 68 F/78 F.

The solar energy contribution increases with an increase in wall thickness up to a 10 inch thick wall. The amount of net solar energy contributed then starts to drop. But it rises again, although slowly, for walls of thickness above 12 inches.

The optimum wall thickness for Windsor is between 8 inches and 10 inches. This is, however, dependent on the indoor temperature float. The value stated is for a 68 F/78 F.

The slight drop in solar energy contribution for walls thicker than 10 inches is due to the fact that the number of wall nodes was kept constant at four. This results in the wall nodes ,in thicker walls, having resistances of a higher value. The drop would probably disappear if the thickness of the wall segments was kept constant. The thicker the segments the poorer is the approximation to the Trombe wall system. A better representation would be to keep the segment thickness associated with a node constant and increase the number of nodes.

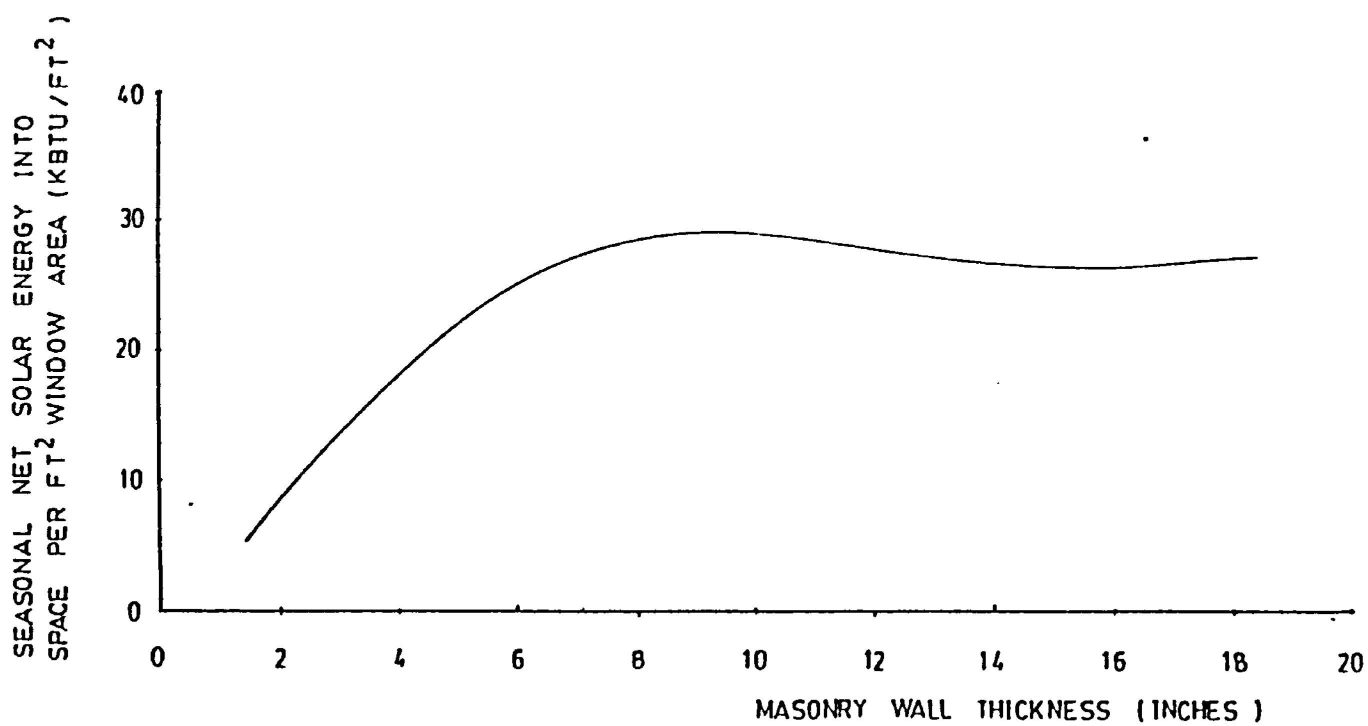



FIG 5.2 Seasonal net solar contribution as afunction of masonry wall thickness. Double glazed window. Indoor temperature float $T_{max}$ = 78 F, $T_{min}$ = 68 F. Average insulated building. (Windsor, Ontario).

5.3 SOLAR ENERGY HEATING AS A FUNCTION OF THERMO CIRCULATION VENT SIZE.

Fig 5.3 shows the effect of varying the area of the top row of vents in relation to the masonry wall area. The vent area ranges from zero to 25 percent of the masonry wall area. Both the top and bottom vents are equal in area.

The optimum size of both the top and bottom vents is 10% of the masonry wall area, divided into 5% for the top vent and 5% for the bottom vent. The increase in solar energy contribution for vent area above the 5%, for either the bottom or top vent, is small.

5.4 SOLAR HEATING FOR 10 INCH WALL AS A FUNCTION OF INDOOR TEMPERATURE FLOAT RANGE.

Fig. 5.4 shows for a 10 inch wall, (which is the optimum for Windsor) behind a double glazed window, the amount of net solar energy contribution per $ft^2$ of glazing area.

Three indoor temperature ranges are shown, $65^oF/75^oF$, $68^oF/78^oF$ and $70^oF/70^oF$.

The best performance is for the $65^oF/75^oF$ range setting. This is followed by the $68^oF/78^oF$ range and

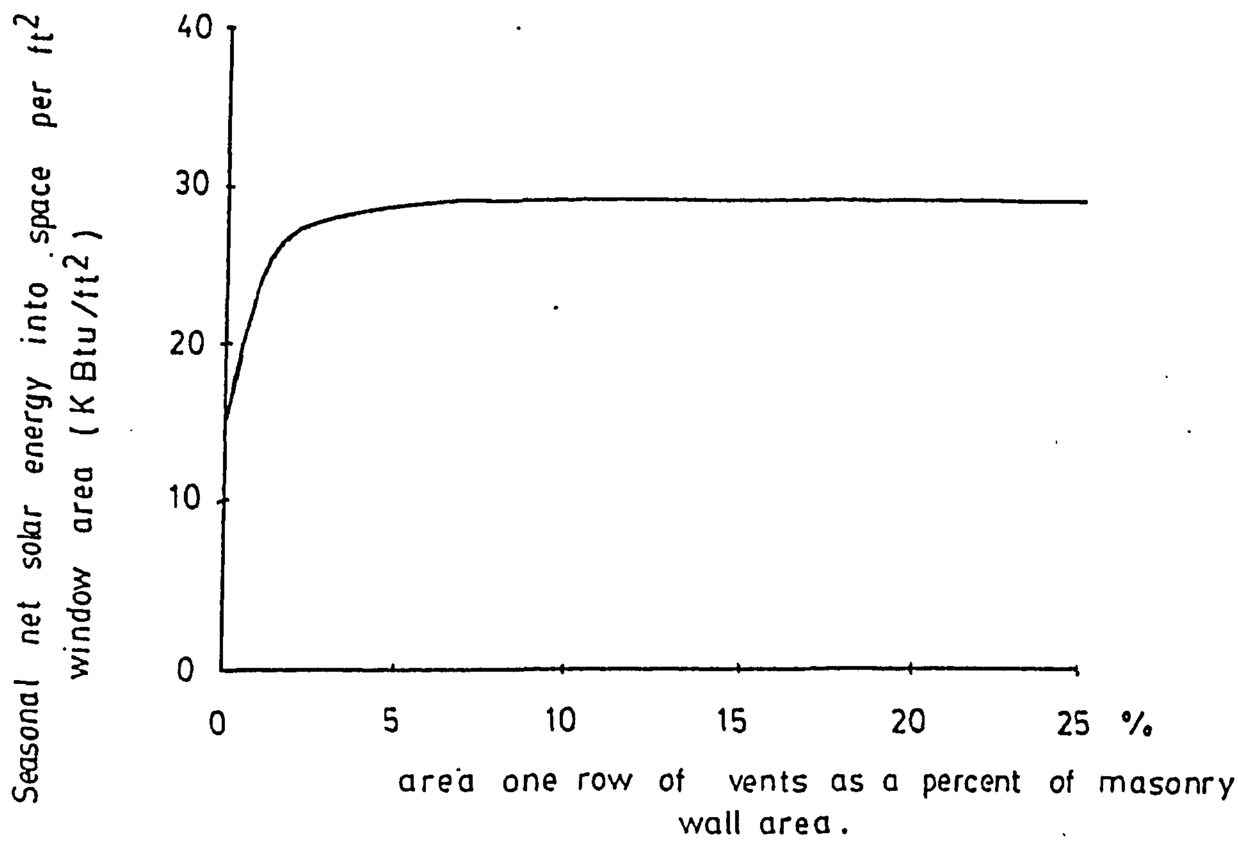



FIG 5.3 Net seasonal solar energy heating as afunction of circulation vent size. Wall thickness= 18 inches. Indoor temperature float $T_{max}$= 78 F, $T_{min}$= 68 F. (Windsor, Ontario).

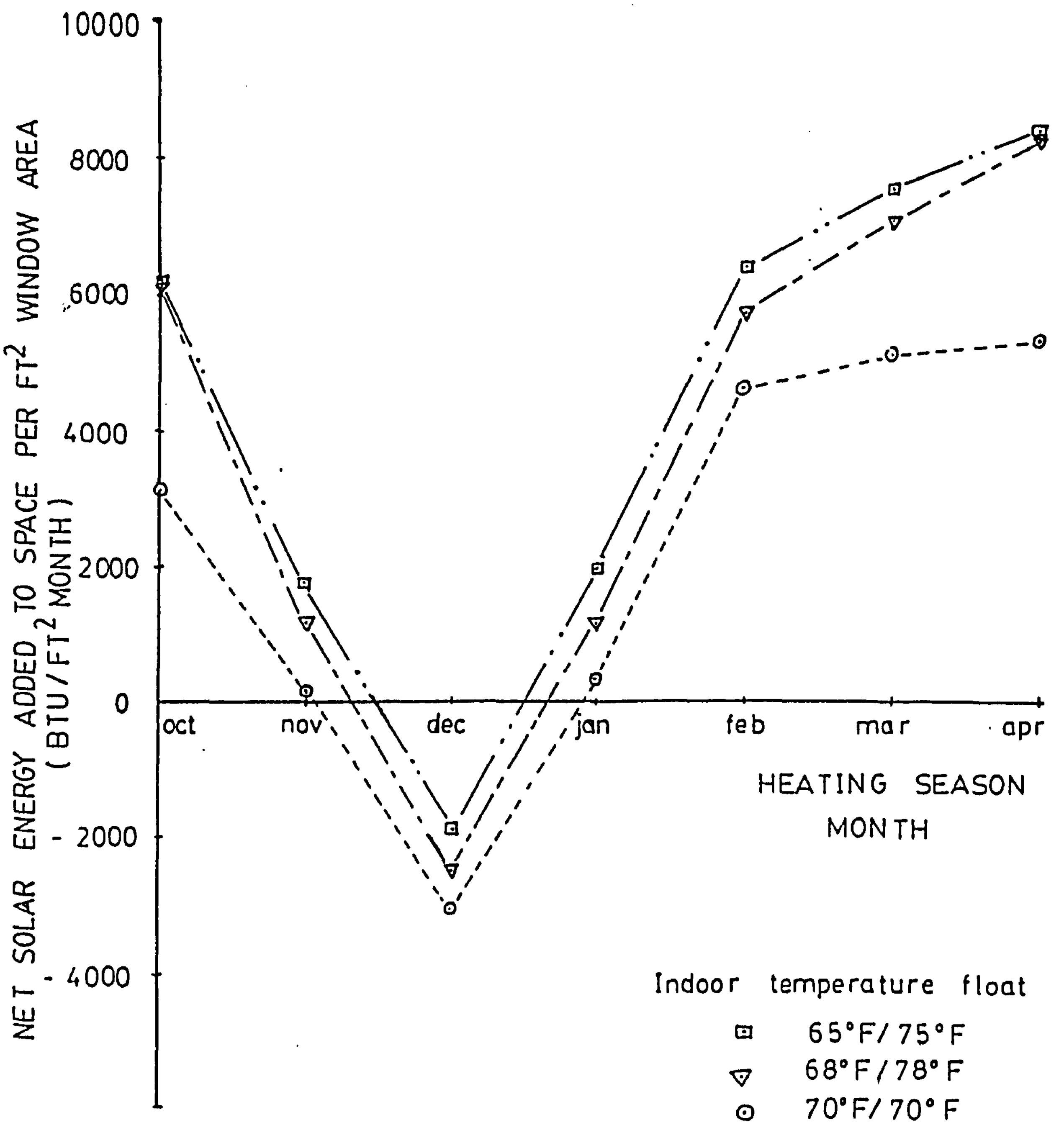



FIG 5.4 Monthly solar energy contribution to space for a ten inch Trombe wall in Windsor. Double glazing. No insulating shutters.

last by the $70^{o}F/70^{o}F$ range. The reason is that when the room temperature is set at a low temperature of $65^{o}F$ it allows more heat to be conducted and convected to it than to a room set at a higher temperature of $68^{o}F$. The indoor temperature rarely exceeds $75^{o}F$ during the heating season. Hence the $65^{o}F/75^{o}F$ range represents the largest solar heating contribution. The $68^{o}F/78^{o}F$ range reduces the value by $3^{o}F$ on the lower end and results in less solar energy used by the room. The $70^{o}F/70^{o}F$ range reduces the range on both the lower side and the upper side. On the lower side reduction by $5^{o}F$ results in less conduction and convection to the higher temperature of $70^{o}F$, with a subsequent decrease in net solar energy contributed. On the upper end limiting the temperature to $70^{o}F$ means solar energy which would raise the indoor temperature above $70^{o}F$ will be let to the outside. This energy is considered lost.

## 5.5 SOLAR ENERGY CONTRIBUTION AS A PERCENTAGE OF TOTAL HEATING FOR A 10 INCH TROMBE WALL AND DOUBLE GLAZED WINDOW.

Fig. 5.5 shows the percentage of solar energy contribution for the heating season for a double glazed masonry wall system. The wall thickness is 10 inches and the room temperature float is $68^{o}F/78^{o}F$. The loss conductance for the rest of the building

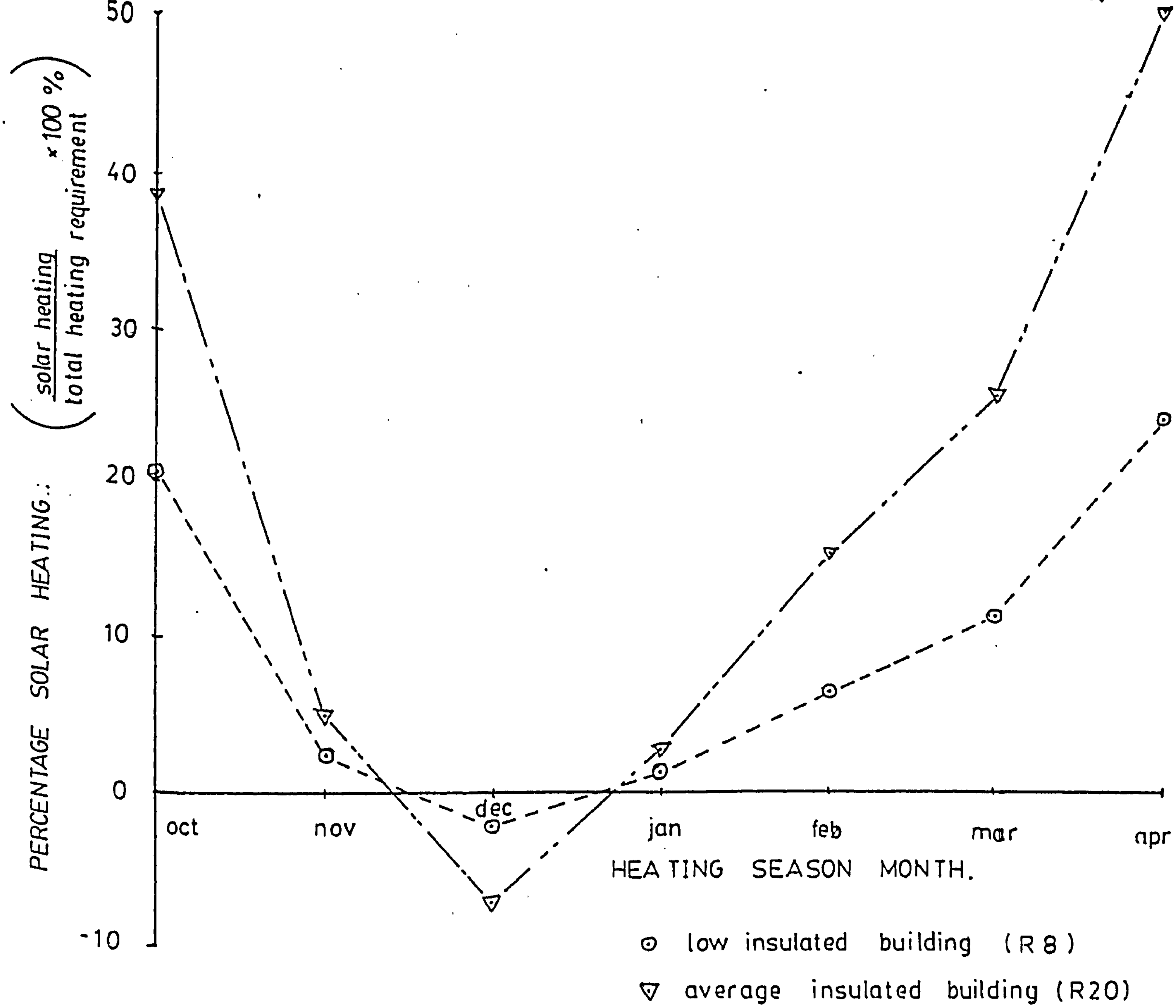



FIG 5.5 Percentage solar heating for low and average insulated buildings. (Windsor, Ontario).

is 1.20 BTU/hr $^{o}$F ft$^{2}$ glazing area. This represents an average insulated house equivalent to average insulation level of R 20.

The largest percentage contribution is during the fall and spring months. This is because the outdoor temperature during these months is moderate hence the heat conducted back through the glazing is less than during the mid winter. The building heating load is also smaller. It was also seen that the amount of solar energy incident on the southern glazing is higher during the fall and spring months resulting in the higher percentage solar heating contribution.

## 5.6 COOLING BY OPENING WINDOWS FOR A 10 INCH TROMBE WALL WITH DOUBLE GLAZED WINDOW, INDOOR TEMP FLOAT 68$^{o}$F/ 78$^{o}$F.

Fig 5.6 shows the amount of solar energy let to the outdoors when the indoor temperature rises above the upper set limit. This is called vent cooling.

The vent cooling is small except for March and April which are moderately warm months and they also have high solar radiation incident on the southern glazing. The results shown are for two cases with no insulating shutters (i) low insulated building (R8) and (ii) average insulated building (R20).

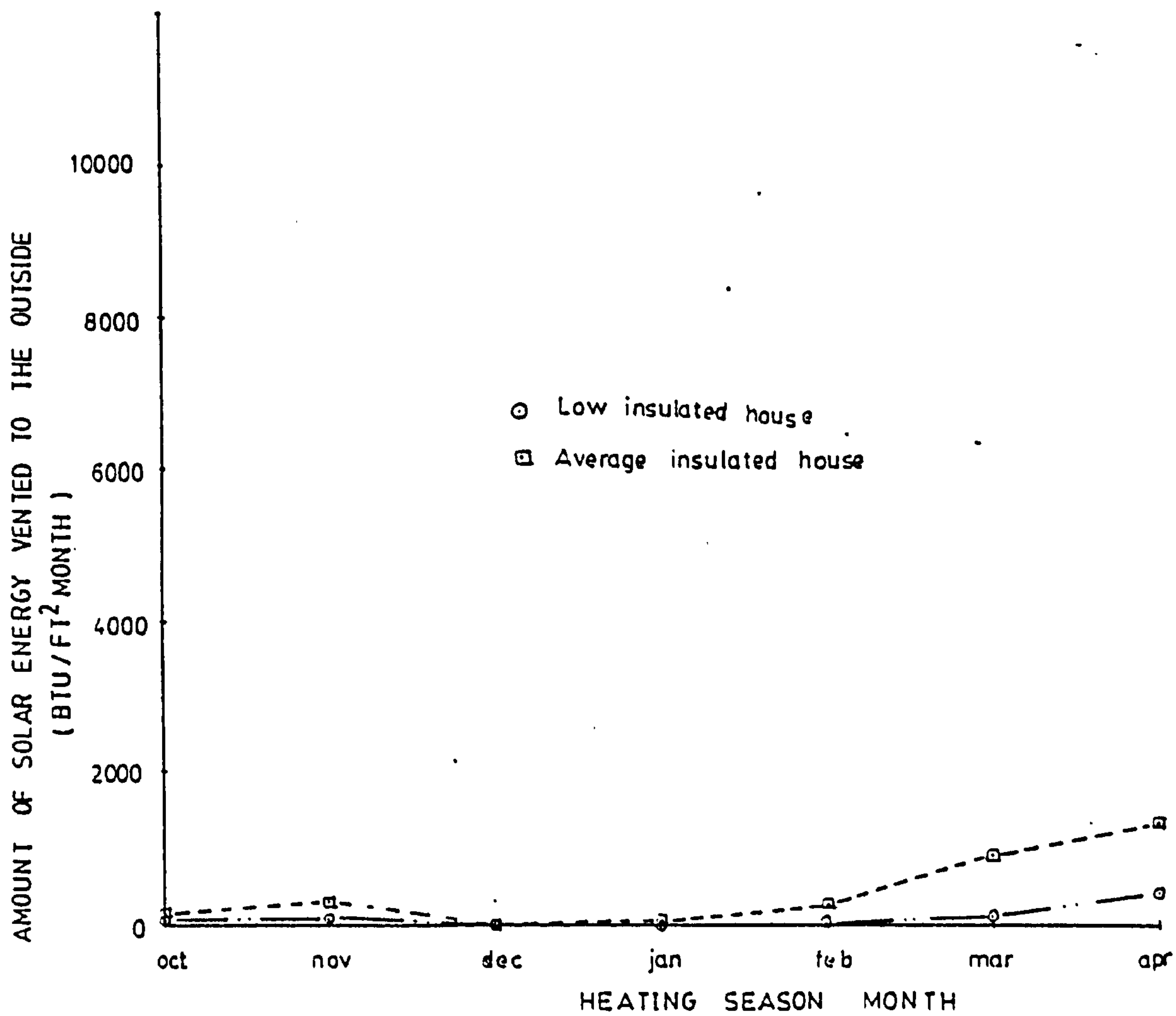



FIG 5.6 Monthly amount of solar energy let to the outside (by opening windows) in order to cool the indoor. Ten inch Trombe wall. Double glazed window. Indoor temperature float $T_{max}$ = 78 F, $T_{min}$ = 68 F. (Windsor, Ontario).

## 5.7 SOLAR ENERGY CONTRIBUTION AS AFUNCTION OF INSULATION LEVEL OF THE BUILDING.

Fig 5.7 shows the effect of the insulation level of the rest of the building on the amount of solar energy contribution for the heating season.

For heavily insulated buildings the net solar energy contribution is small. This is because heavily insulated buildings will overheat and the solar energy will be vented to the outside and considered lost. The amount of net solar energy contribution increases as the insulation level decreases. The plot should flatten out as houses with no insulation are approached.

On the graph, heavily insulated buildings have been defined as those with a ULOAD less than 1.2. This is equivalent to an insulation level greater than R 20, which is about the same level as the Wheatley solar cottage in Ontario. Average insulation is between ULOAD 1.2 and 3.2 representing average insulation between R 20 and R 8. Low insulation is a ULOAD greater than 3.2 which is equivalent to an insulation level of R8 and below. An ordinary frame house of current structure falls at ULOAD=3.2.

For average and low insulated houses the insulation level in the building does not significantly affect the amount of net solar energy contribution to heating the building by a masonry wall passive solar heating system. However, for heavily insulated building the amount of solar energy contribution is reduced due to over heating in the building with subsequent need for cooling, by opening

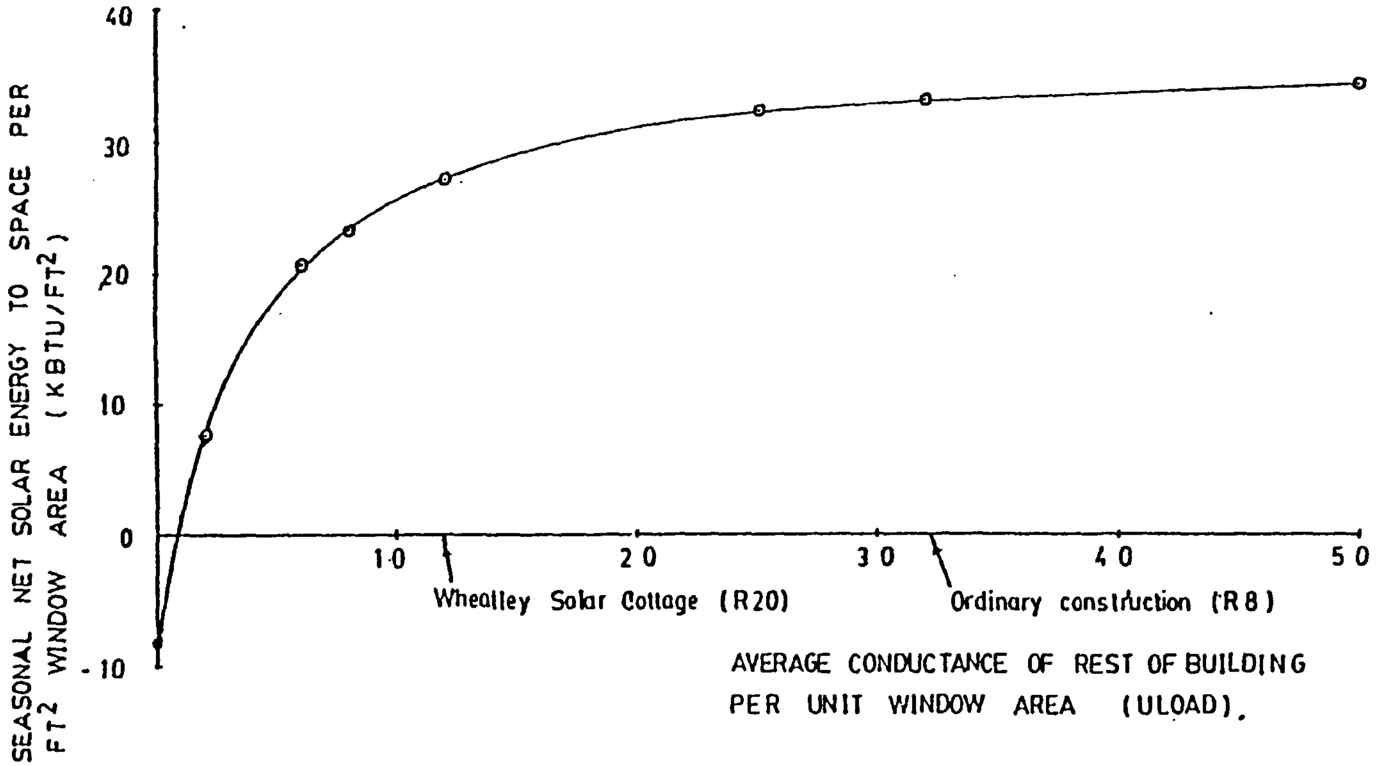



FIG 5.7 Solar energy contribution as a function of insulation level in the rest of the building. (Windsor, Ontario). Building floor area 1000 ft$^2$. Indoor temperature float $T_{max}$ = 78 F, $T_{min}$ = 68 F.

windows or if necessary by auxiliary cooling.

## 5.8 SOLAR ENERGY CONTRIBUTION AS A FUNCTION OF INSULATING SHUTTER RESISTANCE.

The effect of increasing the insulating shutter resistance is shown in Fig. 5.8. The plot shows the law of diminishing returns. The gains due to raising the resistance reduce with the increase in the resistance value.

## 5.9 AUXILIARY HEATING REQUIREMENT AS A FUNCTION OF MASONRY WALL AREA, DOUBLE GLAZED WINDOW (WINDSOR, ONTARIO 1968)

Fig. 5.9 shows the relationship between south facing masonry wall area and auxiliary heat required to heat the building. Bruno (5) showed that for direct gain passive solar windows, an increase in window area in low insulated buildings resulted in a decrease in the auxiliary heating demand. For heavily insulated buildings he showed that an increase in window area resulted in an increase in heating demand.

Fig. 5.9 for a Trombe wall system shows that for this kind of system an increase in the masonry wall area always results in a decrease in the auxiliary heating demand of the building. This is true for both poorly insulated buildings and heavily insulated

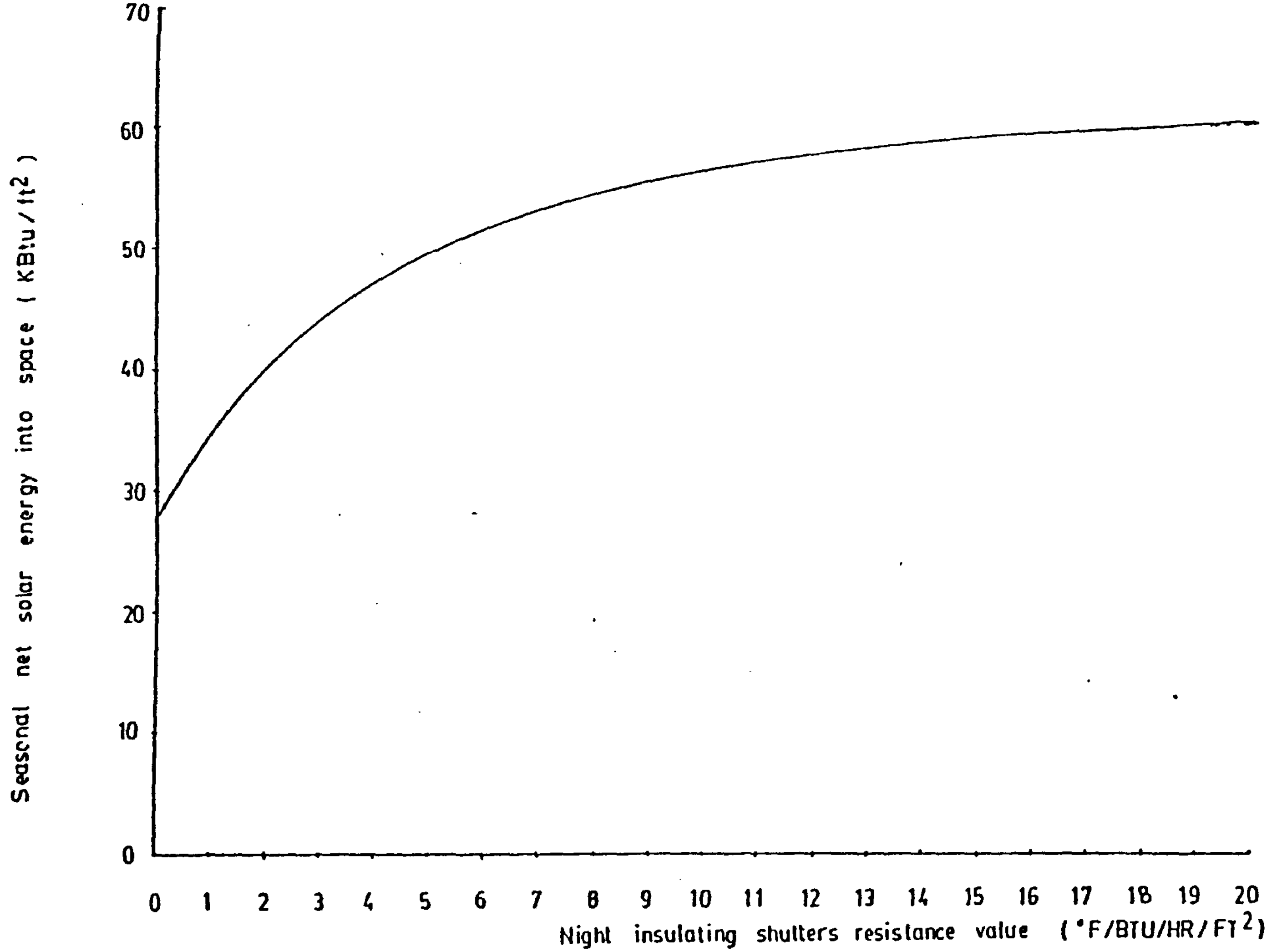



FIG 5.8 Net seasonal solar energy contribution as a function of insulating shutter resistance. Double glazed ten inch masonry wall system. Indoor temperature float $T_{max}$= 78 F, $T_{min}$= 68 F. Average insulated building. (Windsor, Ontario).

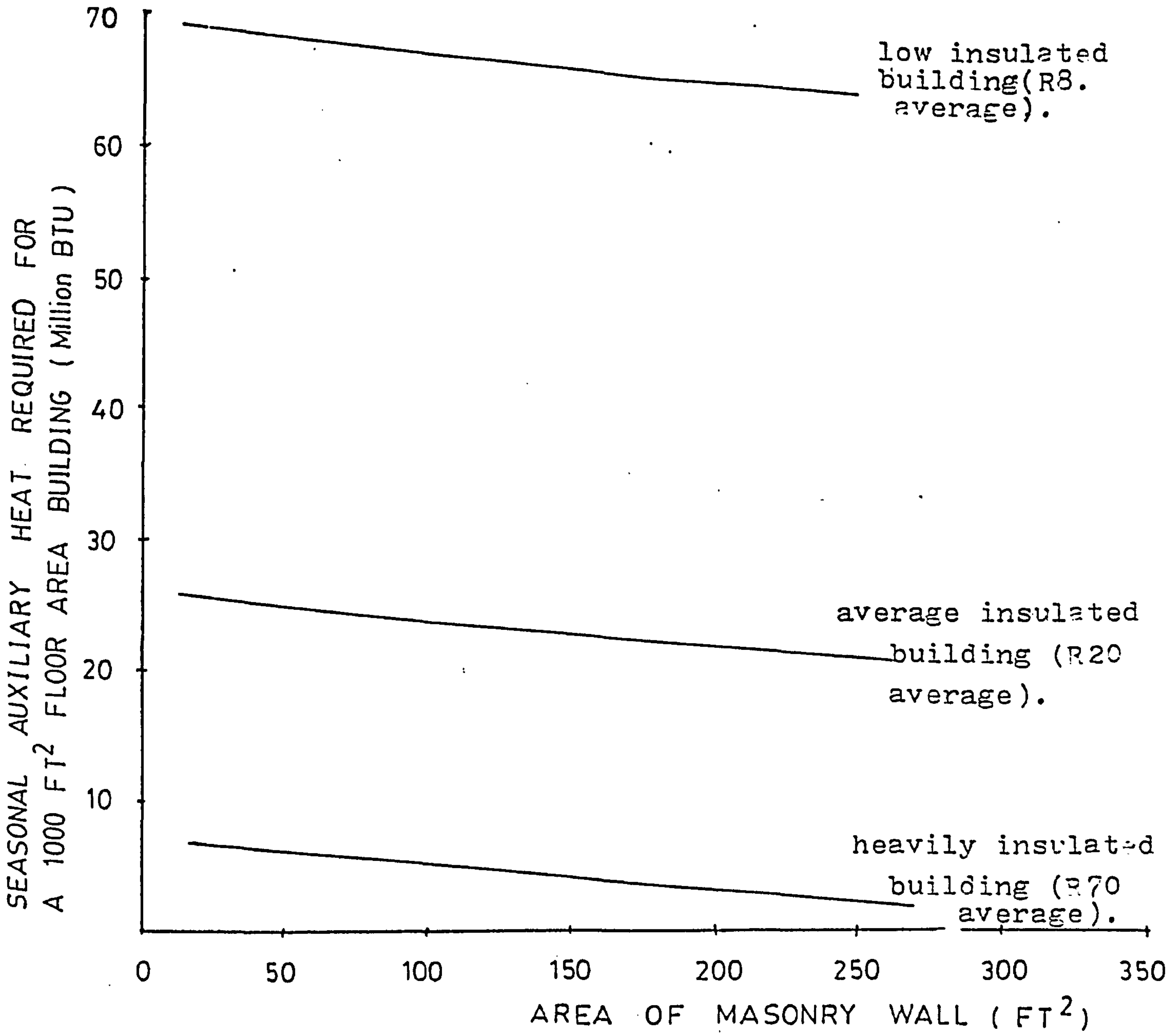



FIG 5.9 Seasonal auxiliary heat requirement as a function Trombe wall area for Windsor, Ontario. 1968.

buildings.

It was found for the Trombe wall system that the auxiliary heat required in all ranges analysed is a linear function of the insulation level in the rest of the building. It is hence not affected by the south masonry wall. This result has been shown before by Jones[10], who came to the conclusion that Trombe wall economics can be treated separately from building insulation economics.

## 5.10 HEAT TRANSFER INTO ROOM NODE FOR A 10 INCH WALL AND DOUBLE GLAZED WINDOW.

The main aim of the Trombe wall system is that it should store most of the solar energy received during the sunshine hours. This stored energy should then be conducted to the room during the night. The heat transfer to the room during the daytime hours should be by convection through the thermocirculation vents in the masonry wall.

Fig. 5.10 shows that heat to the room is convected by thermocirculation through the vents starting for the day shown, 25th January 1968, at 9 am. The conducted heat through the wall reaches the room at 1.00 pm. The convected heat is more than the conducted heat. The conducted heat continues late into

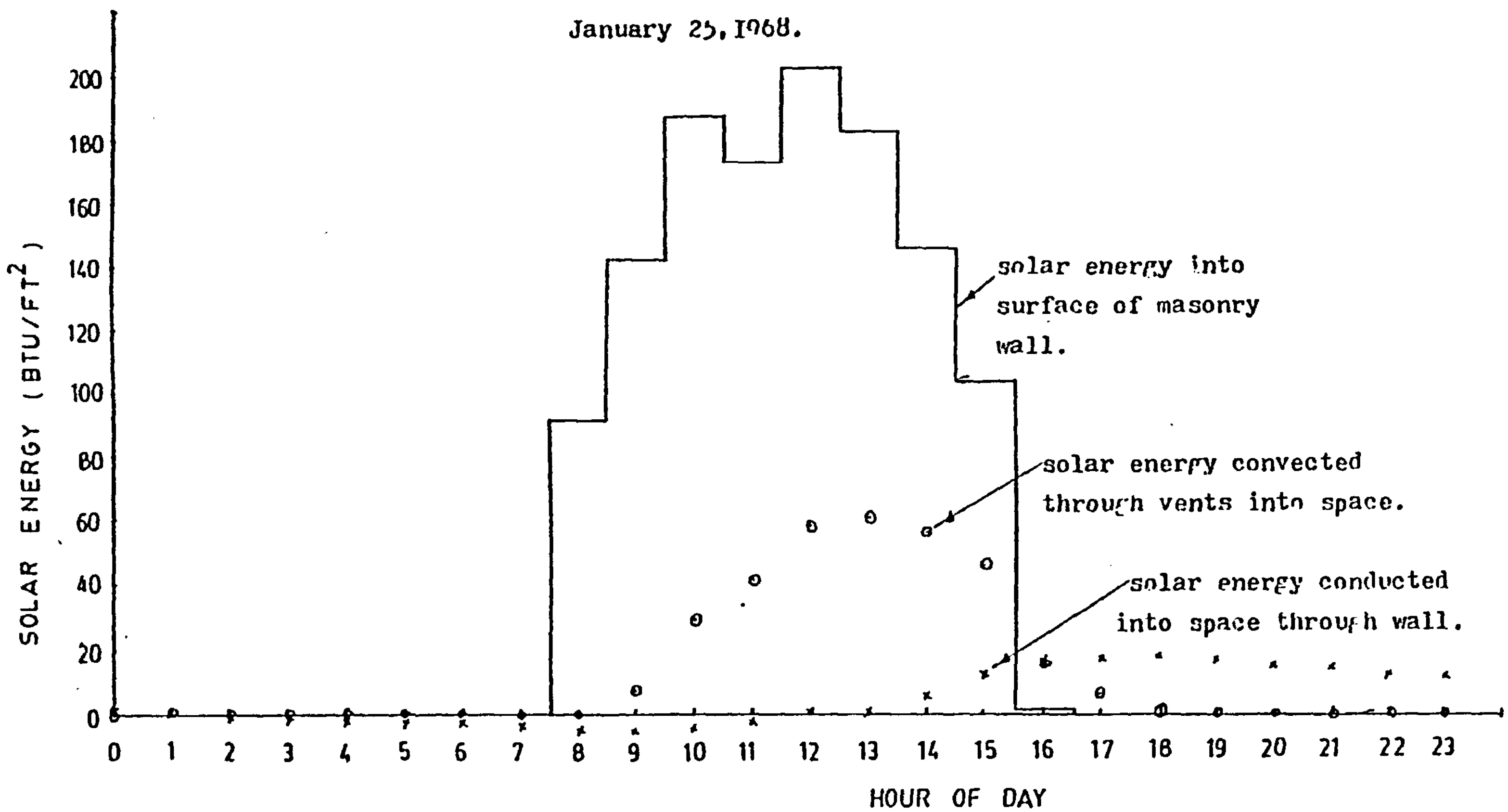



FIG 5.10 Solar conduction and convection into space per ft$^2$ window area for a ten inch thick Trombe wall. Double glazed window. Indoor temperature float $T_{max}$ = 78 F, $T_{min}$ = 68 F.

the night. Some convection occurs through the vents during the early hours of the evening and stops at 7 pm.

A thicker wall means conducted heat will reach the room later in the day. A thinner wall means conducted heat will reach the room earlier in the day resulting in higher room temperatures and lower solar utilization.

## 5.11 MASONRY WALL SURFACE AND ROOM AIR TEMPERATURE PLOTS

Fig 5.11 shows the temperature of the node on the surface of the masonry wall and the temperature in the room (control node) for 25th January 1968 a clear mid winter day. The plots are for a 4 inch wall and a 10 inch wall.

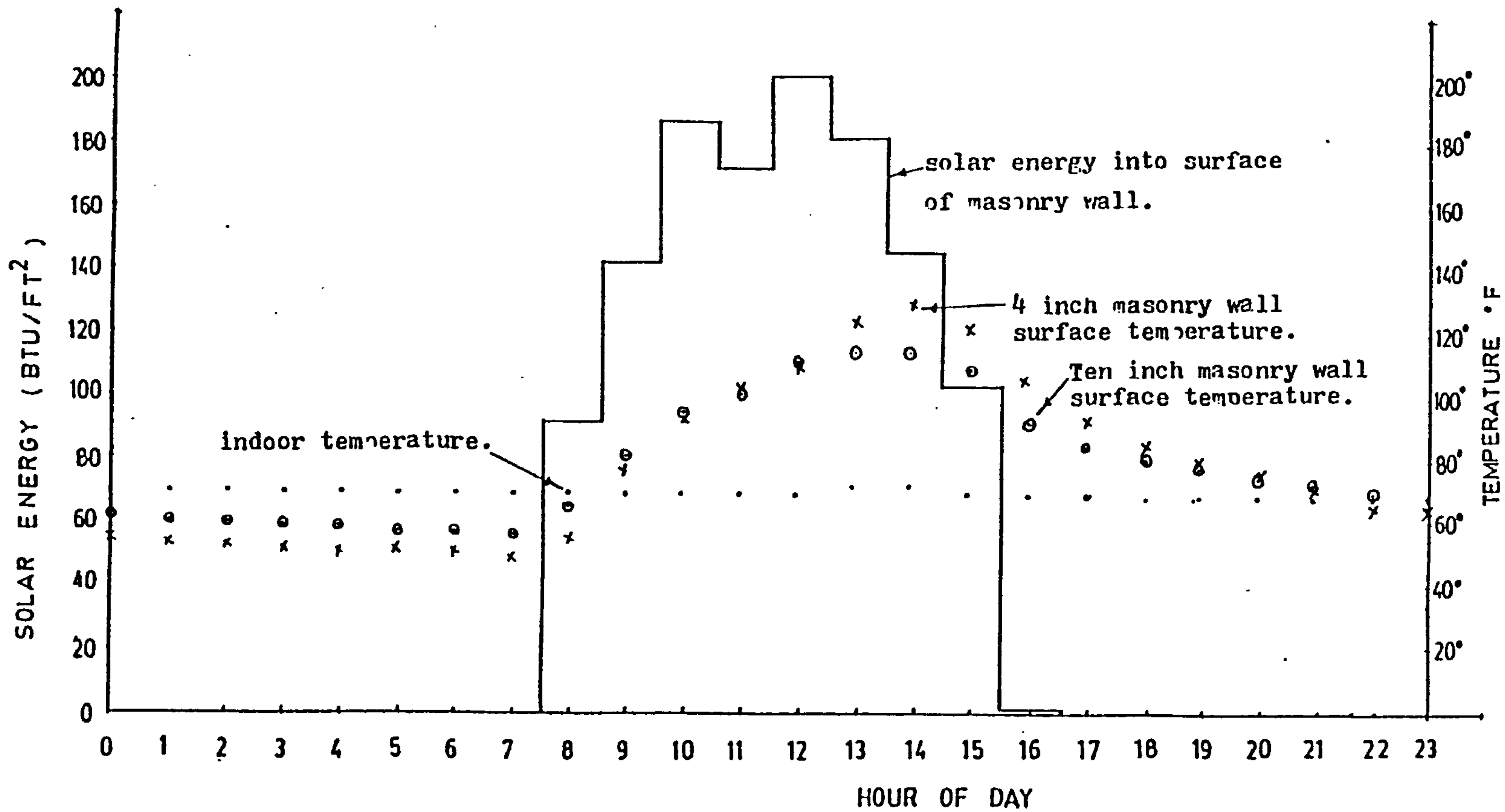



FIG 5.11 Temperature plots for masonry wall surface and indoor. Double glazed four inch and ten inch masonry wallsystem. (Windsor, Ontario). No insulating shutters. Indoor temperature float $T_{max}$ = 78 F, $T_{min}$ = 68 F. Avearge insulated building.

CHAPTER VI

# ECONOMICS

## 6.1 MATERIAL PRICES AND ECONOMIC VARIABLES

The economics of the Trombe wall system was based on material prices and economic predictions for the fall 1981. The prices of materials and other economic variables are shown in Tables 6.1 and 6.2.

## 6.2 LIFE CYCLE COSTING

The life cycle costing formula used was:

$$NPV_s = ES * FC * SPWF_m - CC$$

where

$NPV_s$ = the net present worth value of savings in today's dollars.

ES= energy saved by the passive solar heating system in the first year.

ES=Qwall + Qsolused

where Qwall is the loss which would have occurred if ordinary wall construction, as in the rest of the building, had occupied the Trombe wall area.

Qsolused is the solar energy contribution to the building.

FC= present cost of heating fuel

$SPWF_m$= the series present worth factor adjusted

Table 6.1 Prices of Trombe wall materials. Fall 1981 in Windsor, Ontario.

| | Material | Price in Windsor (Fall 1981) |
|---|---|---|
| 1. | Double glazing and installation. | \$21.00 per $ft^2$ |
| 2. | Night insulating shutters. | \$11.00 per $ft^2$ |
| 3. | Concrete blocks 10" and installation. | \$ 6.25 per $ft^2$ |
| 4. | Electricity cost. | \$ 8.88 per million BTU |
| 5. | Cost of gas. | \$ 5.40 per million BTU |

Table 6.2 Economic Variable

| | Variable | Value (Fall 1981) |
|---|---|---|
| 1. | Inflation | 11.9% |
| 2. | Fuel cost escalation | 20.0% |
| 3. | Interest rates long term | 18.0% |

Source Reference (11)

for fuel cost escalation and inflation.

$SPWF_m$ is calculated using the formula

$$SPWF = \left( \frac{1+fe}{d-fe} \right) * \left(1 - \left(\frac{1+fe}{1+d}\right)^{N}\right)$$

where fe is the fuel cost escalation above inflation

d is the interest on investment loans above inflation.

N is the expected lifetime of the passive solar system.

CC= the extra capital investment to incorporate passive solar heating.

Two cases were considered in the economic analysis. The first case assumed the Trombe wall was a completely new investment. The second case assumed the building would have window area equal to 7 percent of the floor area originally set in the south facing wall. The passive solar investment is then the masonry wall, night insulating shutters if used and any extra glazing above the original 7 percent.

## 6.3 RESULTS

The results for a masonry wall equal to 15% floor area are given in Tables 6.3 (a) (b) (c) and (d). The results show the payback period for a low insulated and average insulated building for base window area 0% and 7%. The results are for a Trombe wall without night insulating shutters and with night insulating shutters. Table 6.3(a) and (b)are for a low insulated building (R8) and Tables

Table 6.3 (a) Payback period for Trombe wall with area equal to 15% floor area. Double glazed window in Windsor. Low insulated building (R8) With night insulating shutters over window.

| Masonry wall area as a percentage of heated floor area | (1)* 7% window base Payback period (years) | (2)+ 0% window base Payback period (years) |
|---|---|---|
| 15% | 27.47 | 47.81 |

Table 6.3 (b) Payback period for Trombe wall with area equal to 15% floor area. Double glazed window in Windsor. Low insulated building (R8) No night insulating shutters over windows.

| Masonry wall area as a percentage of heated floor area | (1)* 7% window base Payback period (years) | (2)+ 0% window base Payback period (years) |
|---|---|---|
| 15% | 22.44 | 31.85 |

* (1) Window area equal to 7% of floor area originally assumed to be in south wall.

\+ (2) No window area originally in south wall.

Table 6.3 (c) Payback period for a double glazed Trombewall with area equal to 15% of the floor area, in Windsor. Average insulated building (R20). With night insulating shutters on windows.

| Masonry wall area as a percentage of heated floor area | (1)* 7% window base Payback period (years) | (2) + 0% window base Payback period (years) |
|---|---|---|
| 15% | 37.17 | 46.25 |

Table 6.3 (d) Payback period for a double glazed Trombe wall with area equal to 15% of the floor area, in Windsor. Average insulated building (R20). No night insulating shutters on windows.

| Masonry wall area as a percentage of heated floor area | (1)* 7% window base Payback period (years) | (2) + 0% window base Payback period (years) |
|---|---|---|
| 15% | 33.77 | 34.11 |

* (1) Window area equal to 7% of floor area originally assumed to be in south wall

\+ (2) No window area originally in south wall

6.3(c) and (d) are for an average insulated building (R20).

The payback period for the masonry wall without night insulating shutters is lower than that for the similar situation with night insulating shutters. This result, however, depends on the cost of the shutters. (which are very expensive here). Cheaper shutters would shift the lower payback period to the night insulated Trombe wall. The payback period for a Trombe wall in a low insulated building is shorter than for a Trombe wall in a higher insulated building. This is because more energy is saved by incorporating the passive solar heating system in the low insulated building.

Life cycle costing for the conventional 30 year period is shown in Table 6.4 for a Trombe wall with area equal to 15% of the floor area. The negative values mean that the investment will not pay back in 30 years.

Table 6.4 Life cycle costing for a Trombe wall of area equal to 15% of the floor area. Auxiliary heating by electricity.

| CASE | Net Present Value Savings per $ft^2$ glazing for N=30 yrs. |
|---|---|
| | ($ per $ft^2$ glazing per yr.) |
| 1. Low insulated building (R8) | |
| a) 0% south window area base. | -$ 2.00 |
| b) 7% south window area base. | $ 7.73 |
| No shutters | |
| 2. Average insulated building (R20) | |
| a) 0% south window area base. | -$ 6.38 |
| b) 7% wouth window area base. | -$ 2.53 |
| No shutters | |
| 3. Low insulated building (R8) | |
| a) 0% south window area base. | -$18.32 |
| b) 7% south window area base. | $ 3.43 |
| With shutters | |
| 4. Average insulated building (R20) | |
| a) 0% south window area base. | -$12.33 |
| b) 7% south window area base. | -$ 7.12 |
| With shutters | |

## CHAPTER VII

## SOLAR ENERGY COMPARISON FOR TORONTO, OTTAWA, AND WINDSOR

Fig. 7.1 shows, for three Ontario cities Windsor, Toronto and Ottawa, the solar energy contribution to heating per $ft^2$ glazing for each of the heating season months. The plots are for an 18 inch thick masonry wall with double glazing and no night insulating shutters.

The graphs are given for comparison of the expected solar energy contribution in each of the cities for a Test Reference Year.

A masonry wall system in Toronto has the highest solar contribution to the building. Toronto is followed by Ottawa and last is Windsor. There is a limitation in the validity of this ranking because both Toronto and Ottawa were run for Test Reference Year 1970 while Windsor was run for the year 1968. (These are the tapes available). There exists a possibility that 1970 was a much clearer year in both Toronto and Ottawa than 1968 was in Windsor. Secondly, there is a slight difference in the way solar radiation data is handled for Canadian cities and U.S.A. cities (Windsor was run with Detroit, Michigan tape). These two points might explain the reason why Windsor has so

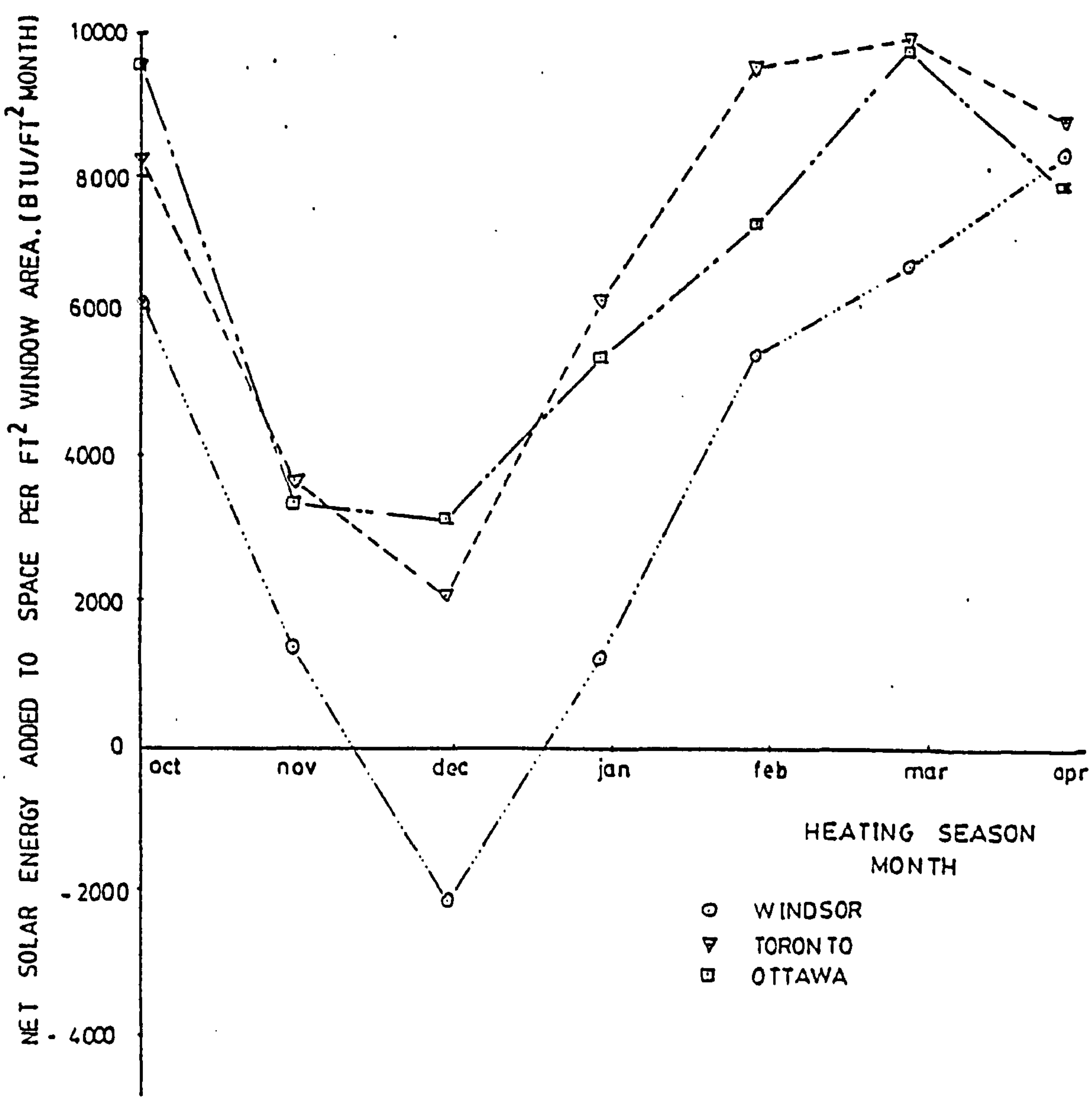



FIG 7.1 Solar energy contribution for an 18 inch thick double glazed Trombe wall in three Ontario cities. Indoor temperature float $T_{max}$= 78 F, $T_{min}$= 68 F. Avearge insulated building.

much lower solar energy contribution among the three cities while it lies southern most.

# CHAPTER VIII

## CASE STUDY FOR WHEATLEY SOLAR COTTAGE

### 8.1 DESCRIPTION OF COTTAGE PASSIVE SOLAR SYSTEM

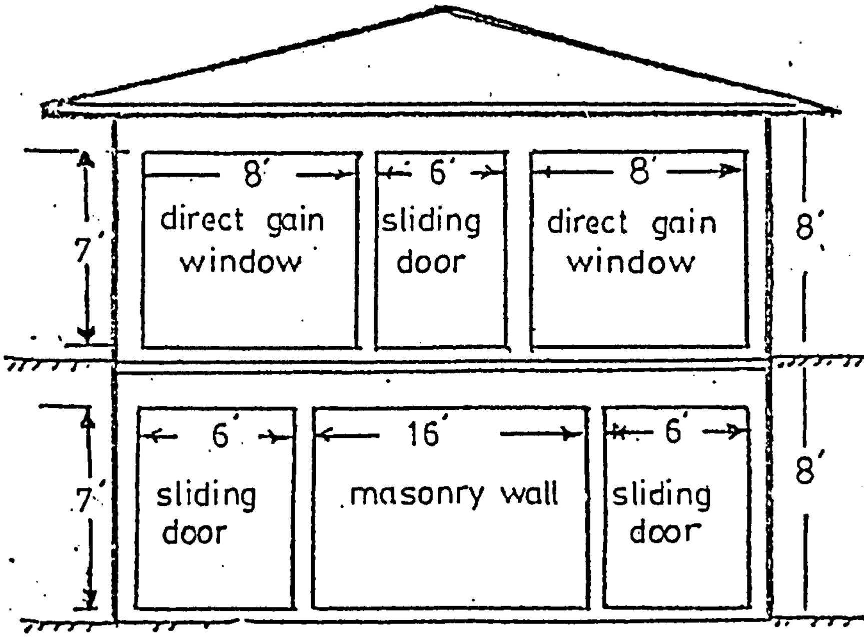
The details of the passive solar heating systems of the solar cottage built in Wheatley Ontario by N.K. Becker and Associates are shown in Fig 8.1 and Fig. 8.2.

The upper floor of the cottage has a direct gain system consisting of two large windows of area 56ft$^2$ each. In the centre there is a 6ft wide sliding door whose area is 42ft$^2$. All the glazing is covered by moveable rolling insulating shutters, on the outside. The shutters can be closed at night during the winter. They can also be partially closed during the summer to reduce solar heat gains. The estimated resistance of the shutters is R 3.4.

The lower floor has a mixed passive solar system incorporating direct gain through a 6 ft. sliding door in each bedroom.

The masonry wall is behind double glazing and its area is 56 ft$^2$ in each bedroom.

The masonry wall has a row of thermocirculation vents at the top and bottom equal to (sum of top and bottom row area) 4 percent of the masonry wall area.




SOUTH ELEVATION

Upper floor area 896 $ft^2$

RWALLS 33 °F $ft^2$hr/Btu.

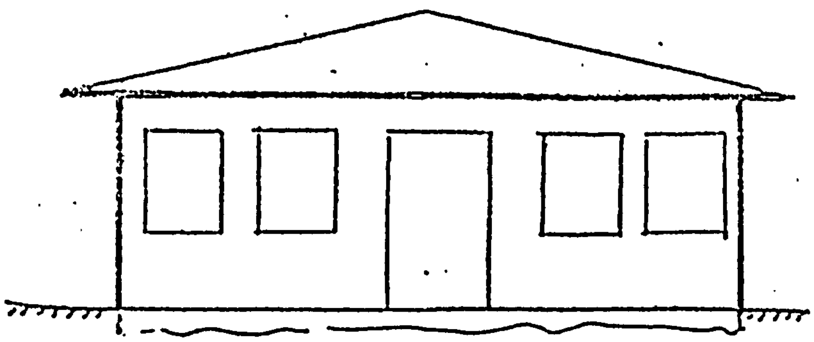
RCEILING 42 °F $ft^2$hr/Btu.

Lower floor area 1024 $ft^2$:

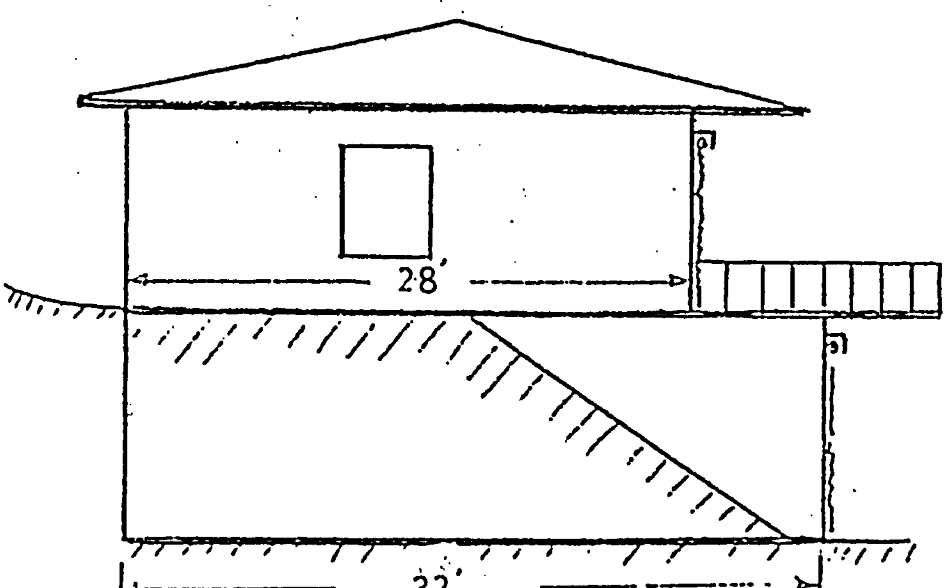
RWALLS 11 °F $ft^2$hr/Btu.

Rceiling 22 °F $ft^2$hr/Btu.

HOUSE AZIMUTH 24° EAST OF SOUTH.



NORTH ELEVATION




EAST/WEST ELEVATION

FIG 8.1 Passive Solar Heating Systems on Wheatley Cottage. (Built by N.K. Becker).

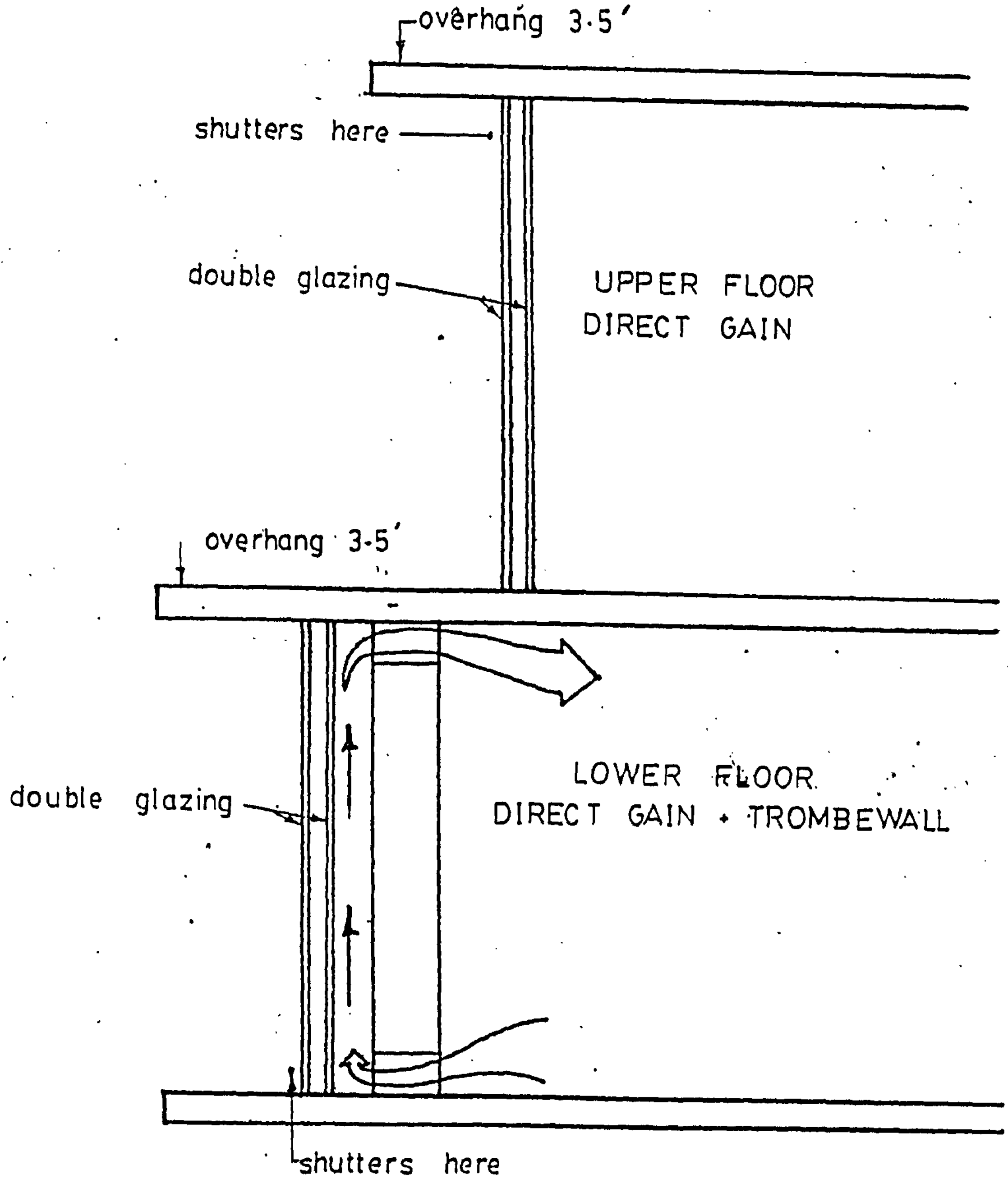



FIG 8.2 Passive Solar Heating systems on Wheatley Cottage. Side view.

The distance between the glazing and the masonry wall is four inches.

The glazing has moveable rolling insulating shutters fitted on the outside. The shutters over the Trombe wall are motor driven.

The total area of southern glazing is about 280 $ft^2$.

The heat loss from the rest of the building(excluding the south facing wall) has been estimated as 0.21 BTU/hr°F per $ft^2$ floor area (12)

## 8.2 SIMULATION MODEL USED AND ASSUMPTIONS

The masonry wall simulation model for the Wheatley solar cottage is shown in Fig 8.3

Since the Trombe wall occupies 40% of the total southern window area, it was assumed that the Trombe wall system would heat only 40% of the building. This gives less conductance for the rest of the building ULOAD=1.2 BTU/hr°F per $ft^2$ glazing. This assumption was made because Pasole does not handle direct gain systems and mixed systems. The Wheatley Cottage has a mixed system.

### 8.2.1 CONDITIONS SIMULATED

The solar cottage simulation was done for a 10 inch thick masonry wall with insulating shutters of an R value of 3.4 of BTU/hr/$ft^2$. The indoor temperature float range was set at 68°F/78°F.

Two azimuth angles were simulated, one facing directly

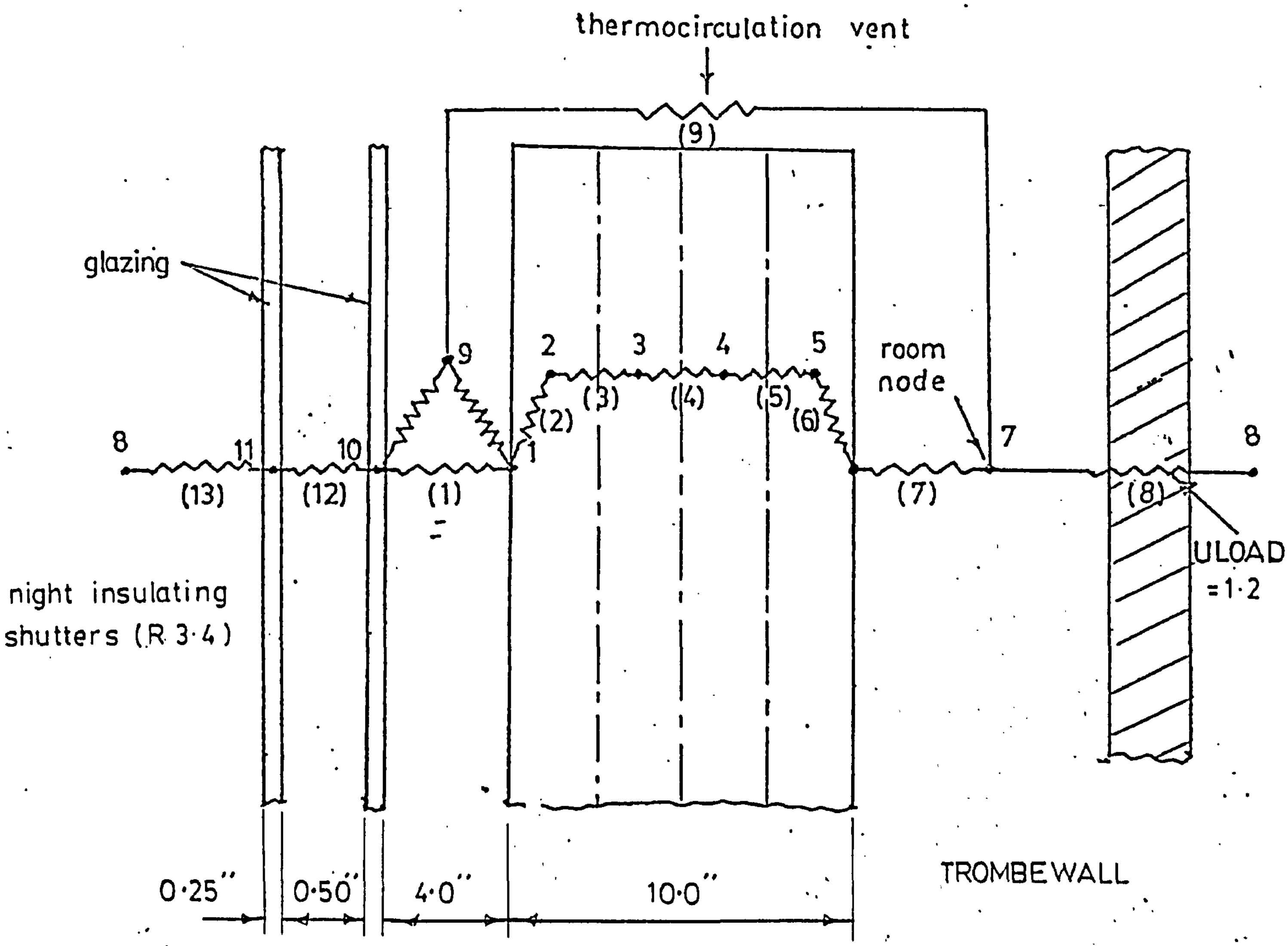



FIG 8.3 Pasole Simulation Model for Masonry wall.

Dimensions as on Wheatley Cottage. ULOAD = 1·2

All dimensions in inches.

south and the other with the windows $24^{o}$ east of south which is the orientation of the Wheatley cottage. The amount of net solar radiation contribution was compared for the two orientations.

Since there was no data available on the other storage masses which will be added into the cottage, overheating of the cottage was not one of the main factors analysed in this simulation.

## 8.3 RESULTS AND DISCUSSION

Fig 8.4 shows the net amount of solar energy contribution to heat the room for each of the heating season months.

For the two orientations plotted it is seen that the Wheatley solar house collects less solar energy in its present orientation than it would if the south facing windows were facing directly south.

The totals for the heating season are

(i) Wheatley cottage azimuth $24^{o}$, 41197 BTU/$ft^2$ glazing per season

(ii) Same system azimuth $0^{o}$, 45047 BTU/$ft^2$ glazing per season, which is a higher value.

### 8.3.1 ECONOMICS

The economics of the masonry wall for the solar cottage is based on prices of the materials used in the Trombe wall and the approximate fuel escalation rate for Ontario in September 1981.

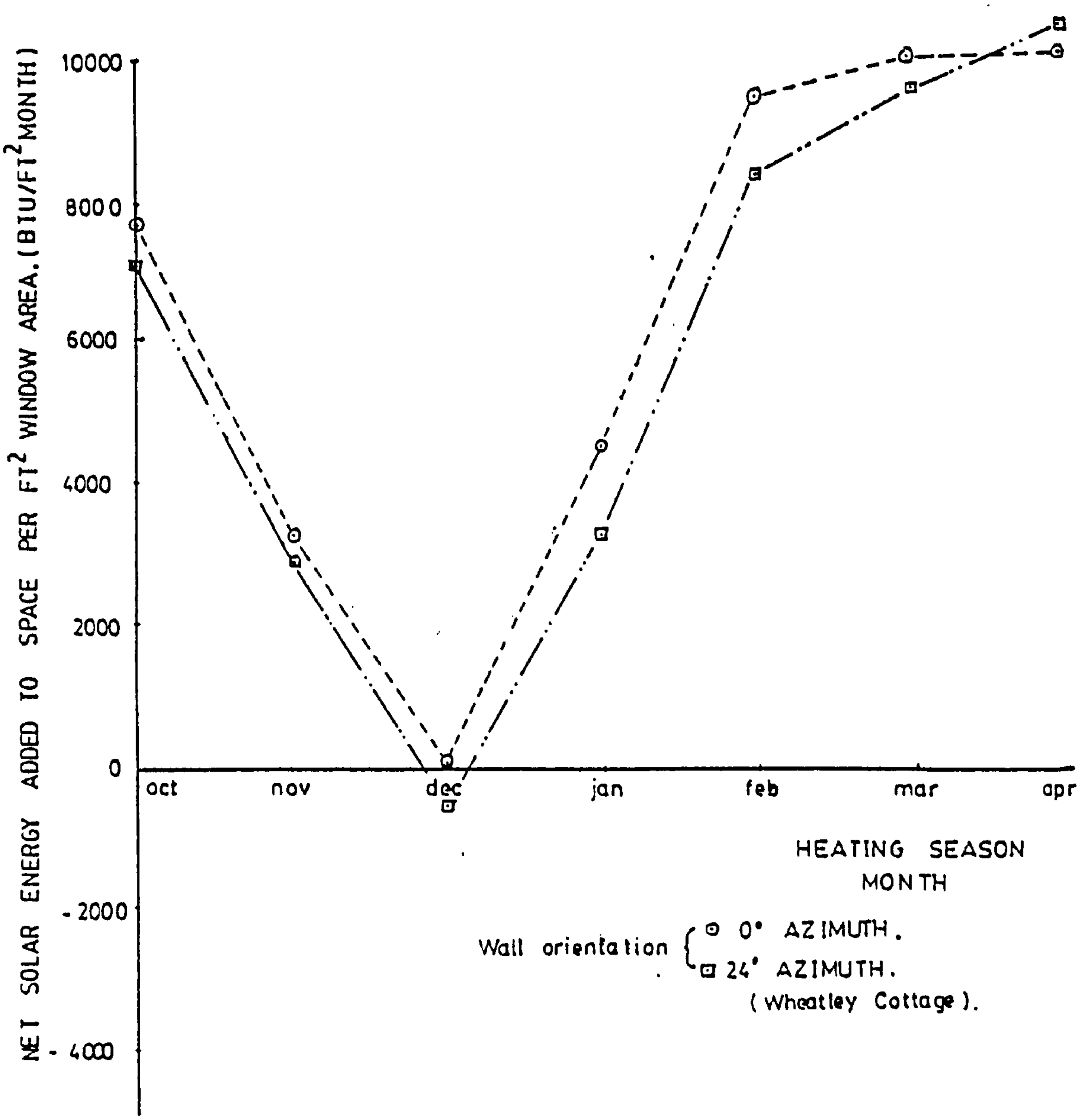



FIG 8.4 Monthly net solar energy contribution to space for a ten inch thick double glazed Trombe wall. Window shutter resistance = R3.4. Indoor temperature float $T_{max}$ = 78 F, $T_{min}$ = 68 F. Average insulation.

The fuel escalation rate was set at 20%

The interest rate on loans set at 18%

Inflation set at 12%

The prices of the masonry wall system were

(i) Masonry wall $6.25 per $ft^2$ area

(ii) Insulating shutters $11.00 $ft^2$ area

(iii) Double glazing + labor $21.00 per $ft^2$ area

(iv) Electricity cost 33¢ per KWH.

A further assumption was that the original southern glazing in the house would have been equal to 7 percent of the heated floor area. Hence the passive solar investment is the masonry wall, the shutters and any extra glazing above 7% floor area.

The payback period of the Trombe wall on the Wheatley cottage is 39 years. Removing the night insulating shutters reduces the payback period to 34 years.

## 8.4 LIMITATIONS AND RESERVATIONS

The Trombe wall simulation done by Pasole assumed no interaction between the direct gain system and the masonry wall system.

In the real case, there will be interaction between the two systems and this will affect the net solar energy contribution.

The simulation assumed that the night insulating shutters were tightly fitted over the glazing. The actual shutters are not tight fitting and air leakage around and between the shutters and the glazing reduces the effective resistance of the shutters greatly.

## 8.5 CONCLUSIONS (WHEATLEY COTTAGE TROMBE WALL)

The following are the conclusions for the Trombe wall on the Wheatley Solar Cottage.

(i) The advantage of using the night insulating shutters is not economical but rather one of adding value to the property and also as a security measure.

(ii) The Wheatley solar cottage receives 8.55% less solar energy than it would if it had its south facing windows facing directly south.

## RECOMMENDATIONS (WHEATLEY COTTAGE TROMBE WALL)

It is recommended that:

(i) Cheaper and tighter fitting shutters be used on the windows to improve the thermal efficiency of the passive solar system. The shutters should also have a higher resistance value.

(ii) Simulation of the whole passive solar system on a program capable of handling mixed systems be carried out.

## CHAPTER IX

## CONCLUSIONS

9.1 The masonry wall with double glazing and no insulating shutters is the best suited for the Windsor area, based on the TRY weather tape for Detroit.

The optimum masonry wall thickness was found to be between 8 inches and 10 inches with total vent area equal to 10% masonry wall area (5% top and 5% bottom).

9.2 The payback period for the masonry wall, without shutters, was found at 1981 prices to be

(i) 22.44 years for a low insulated building(R8)

(ii) 33.77 years for an average insulated building (R 20)

The masonry wall area was 15% of the heated floor area.

9.3 The payback for the same masonry wall with shutters is longer at

(i) 27.47 years for a low insulated building

(ii) 37.17 years for an average insulated building.

9.4 For sizing the area of the masonry wall, it has been shown that no overheating will occur during mid winter in the Windsor area, hence the Trombe wall size can be as large as dictated by the chosen payback period. Larger masonry walls save more energy but have longer payback periods. The size is limited by the fact that an ordinary house with the long side facing south has south facing wall area equal to about 35% floor area.

9.5 The computer simulation showed that one $ft^2$ of double glazed masonry wall passive solar heating system will save the following amount of energy.

(i) 59121 BTU per $ft^2$ of south glazing per heating season for an average insulated building (R20), with night insulating shutters of R3.4.

(ii) 88378 BTU per $ft^2$ of south glazing per heating season for a low insulated building (R8), with night insulating window shutters.

(iii) 41352 BTU per $ft^2$ of south glazing per heating season for an average insulated building (R 20) without insulating shutters.

(iv) 69812 BTU per $ft^2$ of south glazing per heating season for a low insulated building (R8) without insulating shutters.

9.6 Thicker walls above the optimum of 10 inches reduced the solar contribution; so did thinner walls below 8 inches thick.

9.7 For low and average insulated buildings (R value less than R20) the insulation level in the building does not significantly affect the amount of solar energy contribution.

This is true if there is enough thermal storage in the building. This observation does not hold for heavily insulated buildings (above R20, ULOAD less than 1.2).

9.8 The auxiliary heating demand of a building heated by a masonry wall passive solar heating system decreases as the masonry wall area increases for all insulation levels analysed (Below R70 average).

9.9 The thermal advantage of using the Trombe wall was shown to exist for the Windsor area. The choice of using it is mainly determined by economics.

# CHAPTER X

## RECOMMENDATION

The following recommendations arise from the simulation.

10.1 The program Pasole2 can be improved by addition of an extra solar gain route representing a direct gain system. This will allow the possibility of studying mixed systems.

10.2 More connections to represent rooms at fixed temperature surrounding the solar heated room could be added.

10.3 Validation of the approximate results shown in this report is highly recommended.

10.4 An analysis of a water wall performance compared to the masonry wall is suggested. Preliminary results show that their performances are comparable, but complete analysis including economics would give a choice for a builder.

10.5 The effect of the distance between the glazing and the masonry wall should be analysed to determine its effect on the efficiency of the masonry wall system.

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# APPENDIX A

# DEFINITIONS OF SOLAR AND SURFACE ANGLES.

# APPENDIX A.

DEFINITIONS OF SOLAR AND SURFACE ANGLES.(ADAPTED FROM HEATING LOAD AND COOLING LOAD CALCULATIONS) BY DOWN.[13]

The solar and surface angles used in solar heat gain calculations are shown in Fig. A.1. and are defined below.

DECLINATION ANGLE (d). The angle between the direction of the sun's rays and the equator line.

HOUR ANGLE (h). The angle in a horizontal plane, between the direction of the sun's rays at a particular time and the noon azimuth.

ALTITUDE ANGLE (a). The angle, ina vertical plane between the direction of the sun's rays and the tangent to the earth's surface.

AZIMUTH ANGLE (z). The angle in a horizontal plane, between the direction of the sun's rays and the true north-south measured from south (convention).

INCIDENT ANGLE (i). The angle between the direction of the sun's rays and the perpendicular to the surface considered.

LATITUTE ANGLE (B). The angle, on a longitude plane

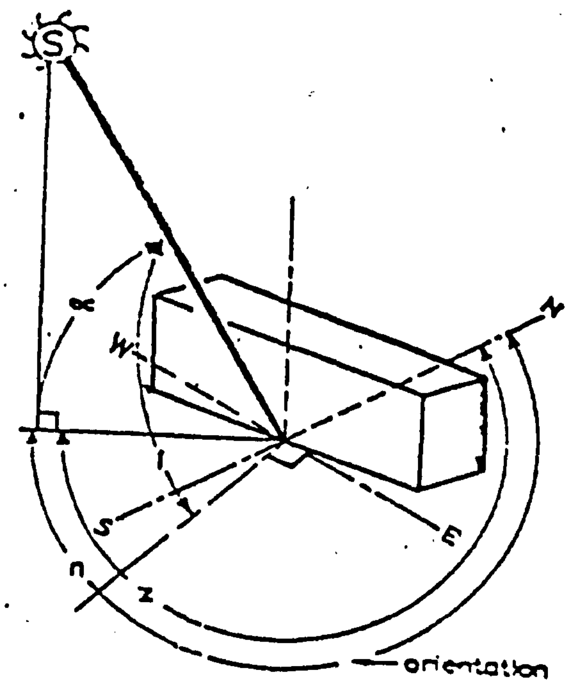


FIG A1. Solar and surface angles.

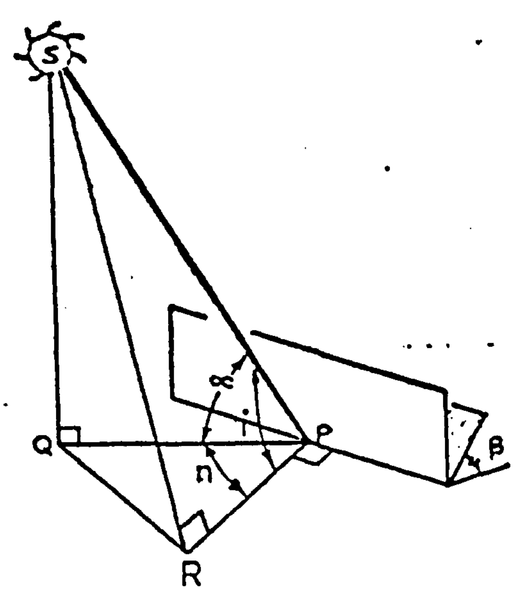


FIG A2. Incident angle for vertical and sloping surfaces.

FROM DOWN. P. G. (13)

subtended at the centre between the equator line and a point at the same longitude on the earth's surface.

LONGITUDE ANGLE. The angle, on a latitude plane, subtended at the centre between the standard meridian passing through Greenwich and a point at the same latitude on the earth's surface.

ORIENTATION ANGLE (WALL AZIMUTH ANGLE). The angle in a horizontal plane, between the normal to a surface and the true north-south line measured from south (convention).

## DERIVATIONS OF SOLAR AND SURFACE ANGLES

DECLINATION ANGLE. The earth's axis is tilted at an angle of $23\frac{1}{2}^{\circ}$ to the plane of orbit around the sun. Fig A1 shows the various positions of the earth during the year-long orbit and the resulting variation in declination. Table A1 gives the values of the declination at monthly intervals. Table A 2 shows dates when various declinations occur.

For declinations south of the equator for northern latitudes or north of the equator for southern latitudes the declination angle is negative and in the following expressions the trigonometrical ratios of these angles must be stated in terms of corresponding positive angles.

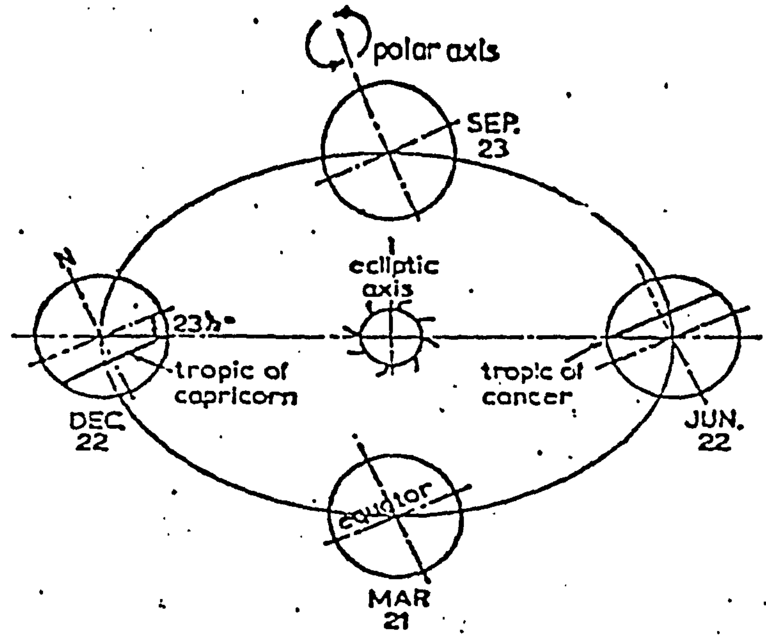


FIG A1 The solar orbit and declination.

TABLE A1 SOLAR DECLINATION AND EXTRATERRESTRIAL INTENSITY[8·1]

| Date | | Declination, North or South (deg) | Extraterrestrial intensity. (Btu/ft² hr) |
|---|---|---|---|
| Month | Day | | |
| Jan. | 21 | 19·9 S. | 456·5 |
| Feb. | 21 | 10·6 S. | 452·1 |
| Mar. | 21 | 0·0 | 445·3 |
| Apr. | 21 | 11·9 N. | 437·9 |
| May | 21 | 20·[illegible] N. | 431·4 |
| June | 21 | 23·45 N. | 427·9 |
| July | 21 | 20·5 N. | 428·3 |
| Aug. | 21 | 12·1 N. | 432·5 |
| Sept. | 21 | 0·0 | 439·2 |
| Oct. | 21 | 10·7 S. | 446·5 |
| Nov. | 21 | 19·9 S. | 452·2 |
| Dec. | 21 | 23·45 S. | 456·8 |

TABLE A2.

| Date | | Declination north or south (deg) |
|---|---|---|
| Month | Day | |
| June | 22 | 23½ N. |
| Apr.<br>Aug. | 21<br>23 | 11½ N. |
| Mar.<br>Sept. | 21<br>23 | 0 |
| Feb.<br>Oct. | 18<br>25 | 11½ S. |
| Dec. | 22 | 23½ S. |

( Source Reference No by P. G. Down)

HOUR ANGLE (h). The earth rotates around its axis, through $360^\circ$, once in 24 hours. If the time (T) is stated as 0-24 hours from midnight and as sun time, (o) then

$$h = \frac{360}{24}(12-T)$$

ALTITUDE AND AZIMUTH ANGLES. Using the declination hour and latitude angles the following are the expressions for the altitude and azimuth angles.

$$\sin \alpha = \sin d.\ \sin B + \cos d.\ \cos B.\ \cos h$$

$$\tan Z = \frac{\sin h}{\sin B.\ \cos h - \cos B \tan d}$$

INCIDENT ANGLE

HORIZONTAL SURFACE. This case is simple since only the vertical angle can affect the incident angle.

$$\begin{aligned} \text{Sin} \quad &= \cos(90-\alpha) \\ &= \cos i \end{aligned}$$

VERTICAL SURFACE. See Fig.

$$QP = SP.\ \cos$$

$$RP = QP.\ \cos n$$

$$\cos i = \frac{RP}{SP} \quad \text{--------} (3)$$

Substitute for RP and QP in equation 3

(o) See definition of sun-time later on.

$$\cos i = \frac{SP.\cos\alpha\cos n}{SP}$$

$$= \cos\alpha\cos n$$

where $n$ = angular difference between the solar azimuth and the wall orientation.

SLOPING SURFACE

$$\cos i = \sin\alpha \,.\, \cos\beta + \sin\beta\cos\alpha\cos n$$

CALCULATION OF SURFACE INTENSITY

The intensity of solar radiation on a surface is the component of the direct solar intensity which is normal to the plane of the surface.

HORIZONTAL SURFACE

$$I_s = I_d \,.\, \sin\alpha$$

VERTICAL SURFACE

$$I_s = I_d \,.\, \cos i$$

which from the preceding section

$$= I_d \,.\, \cos\alpha \,.\, \cos n$$

SLOPING SURFACE

$$I_s = I_d \cos i$$

$$= Id.\ \sin\alpha \,.\, \sin\beta + \sin\beta \,.\, \cos\alpha \,.\, \cos n$$

Diffuse radiation acts on a vertical surface as if it has an incident angle of $60^{\circ}$

## SUN TIME

As the earth orbits the sun, its speed varies depending upon its distance from the sun. As we move closer to the sun the earth slows down and as we move away the earth speeds up. This results in a difference between the time as kept by a watch on earth which does not take into account the variation in the earth's speed and sun time. This difference is called the equation of time E. It is conveniently represented here as a graph showing the difference in time against the month of the year.

To find the sun time at any location on earth the following equation is used.

$$\text{Sun Time} = \text{Standard Time} + E + 4(L_{st} - L_{loc})$$

Where E = the equation of time, from Fig A4 minutes (12)

$L_{st}$ = the standard time longitude line for the time zone.

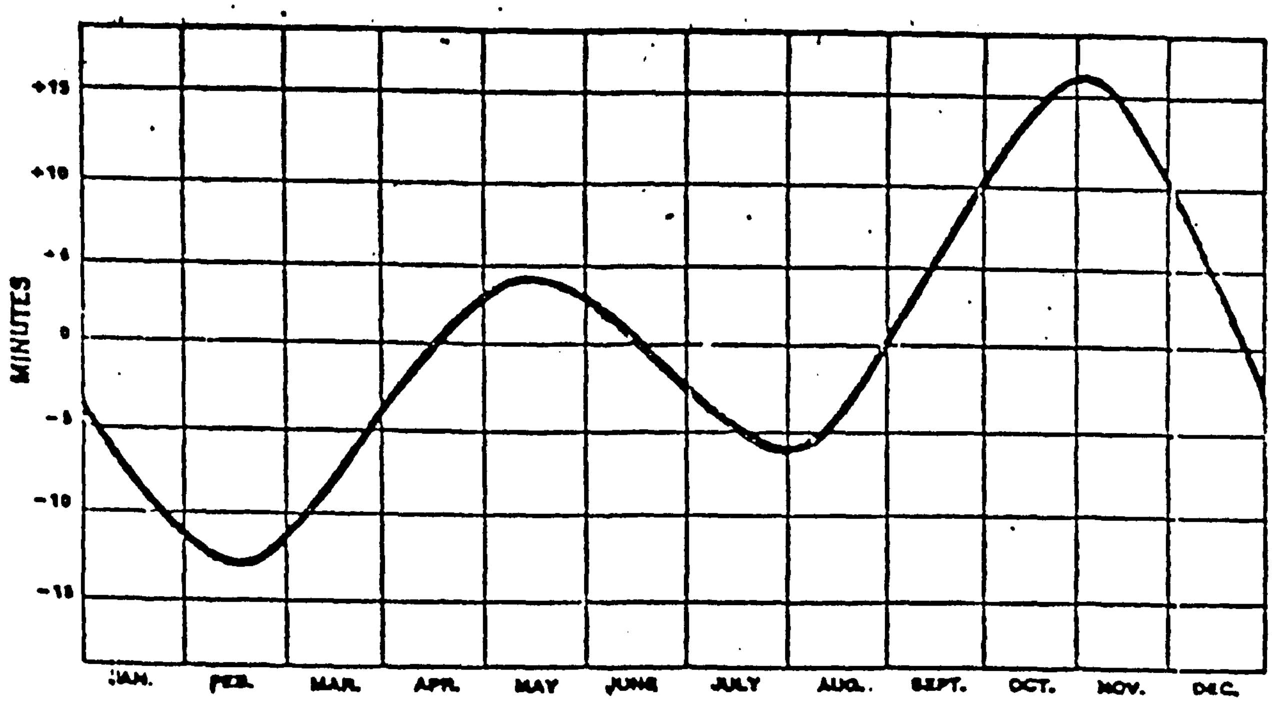


FIG A4. Equation of Time.(2)

APPENDIX B

# PASOLE2

## A GENERAL SIMULATION PROGRAM FOR PASSIVE SOLAR ENERGY

A GUIDE TO THE USE OF PASOLE
AS EXISTS ON THE COMPUTER AT THE
UNIVERSITY OF WINDSOR

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OCTOBER 1981

## CONTENTS.

## EFFECTIVE USE OF THIS MANUAL

This manual provides the JCL and format for input of variables required to run PASOLE2. Also included are instructions on how to run Pasole, the original program. PASOLE2 has more input statements allowing flexibility of changing the thickness of walls and other properties of materials used in masonry wall or water wall passive solar heating systems. The reader is referred to the attached sub appendix 'Pasole, A general simulation program for passive solar energy' by MacFarland which outlines the original program Pasole and explains the meanings of all the variables.

This guide outlines how to run PASOLE2 with Canadian TRY* weather tape data and secondly how to run PASOLE2 with U.S. cities TRY data.

The program is available on tape TA 1219 in the Computer Centre at the University of Windsor. The program is in three files;

FILE 1. PASDAT1 - Weather Program for U.S. cities.
FILE 2. PASDAT2 - Weather Program for Canadian cities.
FILE 3. PASOLE2 - Modified Pasole Program.

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*Test Reference Year Data supplied by National Weather Bureau, Asheville, N.C. and NRC Ottawa.

PREFACE

'Pasole' is a general simulation program which simulates passive solar energy. In its present form it is set out to simulate two models, namely the passive masonry wall, better known as the Trombe wall, and the water wall. Both of these walls are behind some type of glazing.

If one has access to the listing of the program there exists possibilities to simulate all types of passive solar and even active systems. This, however, requires primarily a good working knowledge of FORTRAN and also heat transfer and finite difference mathematics.

The program accomplishes the simulation by dividing the passive system into a thermal network consisting of a number of nodes and connecting conductances. These nodes can have heat sources as well as heat capacitance.

Simultaneous equations are set up and the temperatures of the nodes solved by iteration until the system is in equilibrium.

The program does simulation on an hour by hour basis. Hourly weather is read directly from weather tape records converted into useable format and then used by Pasole. Typical CPU time on the IBM 3031 is 7 minutes for a one year simulation. The time is greatly increased if loss through an optional massive wall is used. It is possible to allow for the control of the temperature of one of the nodes called the control node. This node is set as the room node for both the water wall and masonry wall.

For the period of study the program has the following output by option.

(1) Hourly system data for a chosen day.

(2) Monthly summary of data.

(3) Daily summary of data.

(4) Total summary for whole period.

The summary for the months and the whole period consists of the following.

DEGDAY- Heating degree days.

QOUT- Heat loss back through South Mass Window (SMW) glazing.

QHEAT- Auxiliary heat required by the control node to maintain temperature above lower set point.

QCOOL- Total cooling required by the control node in order to stay below the upper temperature set point.

QSOLAR-Solar radiation absorbed by the primary solar source node. This is the node on the surface of the South Mass Wall.

QLOAD- The building heating load for other than the SMW.*

QACL- Auxiliary cooling required.

QSINC- Solar radiation incident on glazing of SMW.

SOL/USED- The amount of solar energy into the control node from the SMW. Both by convection through the thermocirculation vents and by conduction through the wall.

PCTSOL- The percentage of solar heating. Defined by

PCTSOL = 100 (1 - QHEAT/QLOAD)

Included in this manual is a complete manual of Pasole. A number of modifications have been added to Pasole

* South Mass Wall.(Masonry or Water wall)

so that it can work efficiently on the computer at the University of Windsor and has been subsequently called PASOLE2. These are:

(1) Changes to make the program user-oriented. All variables of importance to a masonry or water wall study are now input by the user on cards.

(2) Changes to make the program have direct access to both Canadian cities TRY weather data and U.S. cities TRY weather.

(3) PASOLE2 outputs the amount of energy into the control node from the SMW.

(4) The loss through the optional massive wall can be connected to a node whose temperature can be set at any value up to 200$^{o}$ F. Setting the node to a temperature value above 200$^{o}$ F. sets it to the outdoor temperature.

This manual outlines how to run PASOLE2 by detailing the input formats and the required JCL. (JCL is subject to change, hence a check with the computer consultants is advisable if any problems are encountered.)

The listing of PASOLE2 is available from the Energy in Buildings Research Group Dept. of Mechanical Engineering. The first part of the listing differs for American and Canadian cities due to the different weather formats. The second part of the program is identical.

INPUT VARIABLES

The variables to be input are as shown in the accompanying figures. To run the program for Canadian cities no input is required for the weather section of the program except the JCL where the station name is identified. Between the weather program and the main PASOLE2 program all the weather data for the whole year is printed out. The format in which it is printed is the same as it is written on the temporary disk. The date is printed in the format MO DA YR, where MO is the month, DA the day, and YR the year. It is necessary that the year of the data be known since this has to be input into the second part of the program.

The following describes the common sections of the program for both Canadian and U.S. cities.

## DATA CARDS FOR PASOLE2

CARD 1. UNITS: FORMAT (I6). This is a flag indicating the units used in the calculation. 1 is for English units and 2 is for Metric units. The program is set to run with only English units. This value should be 1 all the time. The value 2 can be used if the weather data will be supplied on cards.

PRINTH- FORMAT (I6) This is the hourly data print option. If set to 0 no hourly data is printed and 1 all hourly data is printed for a chosen day.

PRINTD- FORMAT (I6) This is the daily data summary print option. If set to 0 no daily summary is printed, if set to 1 a daily summary is printed.

PRINTM- FORMAT (I6) This is the monthly data print option. If set to 0 no monthly data is printed and set to 1 monthly data is printed. It should normally be set to 1.

IDAT-FORMAT (I6) This is the weather data indicator. IDAT takes the value of 1 for data from TRY weather tapes and 2 for data on cards. The data must be in the format

1 x $\underbrace{\text{MODAYR}}_{\text{I6}}$ $\underbrace{\text{24I3}}_{\text{all hours weather data}}$

Four cards for each day in the order: temperature, wind velocity, direct radiation, diffuse radiation.

1.

| UNITS | | | | | | PRINTH | | | | | | PRINTD | | | | | | PRINTM | | | | | | IDAT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

2.

| TILTC | | | | | | AZIMC | | | | | | RESNI | | | | | | RSMWI | | | | | | ROUTS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | |
| | | | • | | | | | | • | | | | | | • | | | | | | • | | | | | | • | | | |

3.

| NSGW | | HAIR | | | | URMW | | | | RWINS | | | | THCW | | | | | THKW | | | | | | | | VSPW | | | | | AW | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| | | | | • | | | | • | | | | • | | | | | • | | | | | | • | | | | | | • | | | | | | • | | | |

CARD 2:

TILTC- The tilt angle of the solar measuring instrument above horizontal. It is used only if data is measured on site (not applicable in this program). Set it to zero always.

AZIMC- The azimuth of the solar measuring pyrometer from south. Not used in this set up. Set it to zero always.

RESNI- The resistance of South Mass Wall night insulating shutters in (DEG $F/BTU/HR/FT^2$). These shutters are on the outside of the glazing.

RSMWI- The resistance between the South Mass Wall and the window glazing in (DEG $F/BTU/HR/FT^2$).

ROUTS- The resistance between the SMW and the room in (DEG $F/BTU/HR/FT^2$).

CARD 3: VARIABLES FOR OPTIONAL MASSIVE EXTERIOR WALL

NSGW FORMAT (I 2)- The number of wall segments in the extra massive wall. This wall is used to simulate loss through a massive wall to take into account building storage effects. Set it to zero if no optional massive wall is used.

HAIR- Outside air film coefficient for the option extra massive exterior wall.

URMW- Room to wall conductance value. It includes the value for any internal resistance.

RWINS- Resistance of exterior insulation on the extra massive wall.

THCIN- The thermal conductivity of the option exterior wall material BTU/HR/FT$^2$/FT.

THKW- The thickness of the optional exterior massive wall in inches.

VSPW- The wall material volumetric heat capacity BTU/$^{o}$F/FT$^3$.

AW- The wall area/SMW glazing area ratio.

<u>CARD 4</u>: SMW DATA

NGL- Number of glazing. Can be zero.

HGHT- Height of the SMW in feet.

ULOAD- The static room heating load coefficient per unit SMW glazing area ($BTU/HR/^{\circ}F/FT^2$). This does not include losses through the SMW or the optional massive exterior wall.

KWALL- The type of wall flag. 1 stands for a water wall and 2 is for a masonry wall.

KVENT- The type of thermo siphoning vents flag.
0 = no thermo circulating vents
1 = vents always open
2 = no reverse thermo siphoning permitted
4 = thermostatically controlled vents, no reverse thermo siphoning permitted.

4.

| NGL | | HGHT | | | | ULOAD | | | | | | KWALL | | | | | KVENT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | |
| | | | | . | | | | | . | | | | | | | | | | | | | |

5.

| TILTG | | | | | AZW | | | | | ALF | | | | | GRAV | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| | | | . | | | | | . | | | | . | | | | | . | | |

6.

| TGL | | | | | | | THCGL | | | | | AIRGAP | | | | | | | TRCOAT | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 |
| | | . | | | | | | . | | | | | | . | | | | | | | . | | | | | | | | |

CARD 5: SMW DATA

TILTG- The tilt of the SMW glazing from horizontal in degrees.

AZW- The azimuth of the SMW measured from south, in degrees. Positive in clockwise direction.

ALF- The wall solar absorbtivity. Taken to be close to 1 for a black painted surface.

GRAV- The acceleration due to gravity in English units FT/S/S. (Set to metric if using metric weather data,)

CARD 6: SMW DATA

TGL- The thickness of each glazing pane in feet.

THGL- The thermal conductivity of the glazing pane in BTU/HR/FT$^2$/FT.

AIRGAP- The size of the airgap between the panes if more than single glazing is used. (FT)

TRCOAT- The transmittance of the glazing coating. Taken as 1.00 for clear glass with no coating on the inside.

CARD 7: SMW DATA

AVOAG- The area of one row of vents in the SMW per unit area of SMW glazing.

ASOAG- Wall to glazing air space flow area per unit SMW glazing area.

CPMR- SMW heat capacitance in (BTU/$^{o}$F per unit SMW glazing area).

THCON- The thermal conductivity of the SMW (masonry wall only) (BTU/HR/$^{o}$F/FT).

VOLSP- The masonry volumetric heat capacity (BTU/$^{o}$F/FT$^{3}$).

NSEG- The number of segments into which the masonry wall is divided. This value is normally set at 4.

7.

| AVOAG | | | | | | | | ASOAG | | | | | | | | CPMR | | | | | THCON | | | | | VOLSP | | | | | NSEG | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 |
| | | | . | | | | | | | | . | | | | | | | | . | | | | | . | | | | | . | | | | | |

8.

| TCMINN | | | | TCMIND | | | | TCMAXN | | | | TCMAXD | | | | ALAT | | | | | IDPRYR | | | | DLONG | | | | | KCALC | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | |
| | | | . | | | | . | | | | . | | | | . | | | . | | | | | | | | | . | | | | | | | |

9.

| CDIS | | | | | OHANG(1) | | | | | | OSEPR(1) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | | | | | | | | | | | | |
| | | . | | | | | | . | | | | | | . | | |

CARD 8

TCMINN- The control node minimum set night temperature. Below this value auxiliary heat will be applied to the control node to maintain this temperature. ($^{o}$F).

TCMIND- The control node minimum set day temperature. ($^{o}$F).

TCMAXN- The maximum night temperature setting for the control node. If the temperature tries to go above this point either vent cooling or auxiliary cooling will be employed depending on whether the outside temperature is lower or higher than TCMAXN.

TCMAXD- The maximum day temperature setting for the control node.

ALAT- Site latitude in Degree North.

DLONG- The difference between the location longitude and the standard time meridian longitude.

IDPRYR- The number of days in the year.

KCALC- Calculation option.
1 for iterated solution.
2 simplified solution. Constant conductance values.

CARD 9

CDIS- Vent discharge coefficient. Normally set it 0.80.

OHANG(1)- The ratio of the perpendicular distance between the top of the glazing and the end of the overhang to the vertical length of the glazing measured along the glass.

OSEPR(1)- The ratio of the height of the tip of the overhang above the top of the glazing to the vertical length of the glazing measured along the glass.

CARD 10.

THICK- The thickness of the masonry wall in feet.

TROOM - The temperature of the node on the outside of the optional massive wall. When set to a value above 200° F the node is at outside temperature. If set to below 200° F the node takes on the set value, and represents loss to a room at the set temperature.

CARD 11

INDATE- Starting date of simulation in the format MODAYR.

IO1- The day on which detailed hourly data will be printed if PRINTH has been set to 1.

NDAY1- The number of simulated days. Especially useful if days are less than 32. If days are higher than 32, the number of months NMO is used to determine length of simulated period.

KWALL- SMW option
1 - water wall
2 - masonry wall

NMO- Number of months to be simulated.

MOSH1- Month in which night insulating shutters are reversed and used as daytime shutters, i.e. start of summer.

MOSH2- Month in which night insulating shutters start to operate as closed at night. Start of winter (heating season).

TMORN- Time when shutters open in the winter in the morning.

TEVEN- Time when shutters close for the night.

10.

| THICK | | | | | | | TROOM | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | |
| | | | . | | | | | | | . | |

11.

| INDATE | | | | | | IO1 | | | | | | | NDAY1 | | | KWALL | | | NMO | | | MOSH1 | | | MOSH2 | | | TMORN | | | | | TEVEN | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | . | | | | | . |

PASOLE2 WITH CANADIAN DATA

With the above input the set up to run PASOLE2 with Canadian data is as follows.

```
//JOBNAME JOB (XXXXXXXXXX,9,9),'NAME',CLASS=L
//STEPI  EXEC  FORTGCLG
//FORT.SYSIN  DD  DSN=PASDAT2,UNIT=3400-4,VOL=SER=TA1219,
//      LABEL=(2,SL),DISP=OLD
//GO.FT12F001  DD  DSN=ENCORE.OTTAWA,
//    DISP=SHR,UNIT=3330,VOL=SER=DISK01
//GO.FT13F001  DD  DSN=OTTAWA.WEATHER,UNIT=3330,
//    VOL=SER=WORK30,DISP=(NEW,PASS),SPACE=(2728,367),
//    DCB=(RECFM=VS,LRECL=2724,BLKSIZE=2728)
//GO.SYSIN  DD  *
/*
//GO.DELET  DD  DSNAME=*.STEP1.LKED.SYSLMOD,DISP=(OLD,DELETE)
/*
//  EXEC  FORTGCLG
//FORT.SYSIN  DD  DSN=PASOLE2,UNIT=3400-4,VOL=SER=TA1219,
//      LABEL=(3,SL),DISP=OLD
//GO.FT01F001  DD  DSN=OTTAWA.WEATHER,UNIT=3330,
//     VOL=SER=WORK30,DISP=(OLD,PASS)
//GO.SYSIN  DD  *

   PASOLE DATA CARDS.
//
```

## PASOLE2 WITH U.S. DATA

To run PASOLE2 with U.S. data the weather program is borrowed from ESP.[10] The following ESP data cards are necessary. The weather program will output information regarding the site location and weather data for selected days. The weather data output is dry bulb temperature, wind velocity, direct and diffuse solar radiation on a horizontal surface.

The set up to run PASOLE2 with U.S. data is then

```
//JOBNAME JOB (XXXXXXXXXX,9,9),'NAME',CLASS=L
//STEP1  EXEC FORTGCLG
//FORT.SYSIN  DD  DSN=PASDAT1,UNIT=3400-4,VOL=SER=TA1219,
//     LABEL=(1,SL),DISP=OLD
//GO.FT12F001 DD DSN=ESP1.TRY.DETROIT,DISP=SHR,
//   UNIT=3330,VOL=SER=DISK01
//GO.FT13F001  DD  DSN=DETROIT.WEATHER,UNIT=3330,
//  VOL=SER=WORK30,DISP=(NEW,PASS),SPACE=(2728,367),
//   DCB=(RECFM=VS,LRECL=2724,BLKSIZE=2728)
//GO.SYSIN  DD  *
    WEATHER AND STATION DATA.
/*
//GO.DELET    DD  DSNAME=*.STEP1.LKED.SYSLMOD,DISP=(OLD,DELETE)
/*
//  EXEC  FORTGCLG
//FORT.SYSIN  DD  DSN=PASOLE2,UNIT=3400-4,VOL=SER=TA1219,
//     LABEL=(3,SL),DISP=OLD
//GO.FT01F001  DD  DSN=DETROIT.WEATHER,UNIT=3330,
//   VOL=SER=WORK30,DISP=(OLD,PASS)
//GO.SYSIN  DD  *
          PASOLE  DATA  CARDS.
//
```

## TITLE DATA

| CARD TYPE | | TITLE PAGE DATA |
|---|---|---|
| 1 2 3 | 4 5 | 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 |
| W T A | | |
| W T B | | |
| W T C | | |

## STATION AND IDENTIFICATION

| CARD TYPE | | WEATHER STATION ID | SITE ID | DATE MO | DATE DAY | DATE YR |
|---|---|---|---|---|---|---|
| 1 2 3 | 4 5 | 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 | 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 | 4 5 | 6 7 | 8 9 |
| W T D | | | | | | |

## STATION AND SITE DATA

| CARD TYPE | | WEATHER STATION NUMBER | SITE NUMBER | | STATION ELEVATION | SITE DATA: LATITUDE | SITE DATA: LONGITUDE | SITE DATA: ELEVATION | SITE DATA: TIME ZONE | | SITE DATA: CLEARNESS NUMBERS SUM. | SITE DATA: CLEARNESS NUMBERS WIN. | | WEATHER YEAR | | NO PRINT SCHEDULE | DAYLIGHT SAVINGS TIME: OPTION | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 2 3 | 4 5 | 6 7 8 9 0 | 1 2 | 3 | 4 5 6 7 8 | 9 0 1 2 3 | 4 5 6 7 8 | 9 0 1 2 3 | 4 5 | 6 | 7 8 9 | 0 1 2 | 3 | 4 5 6 7 | 8 | 9 0 | 1 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 |
| W T E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| CARD TYPE | | | INDEX NO | | STARTING DATE | | | | | | ENDING DATE | | | | | | PRINT OPTION | | | SELECTED HOURS FOR OUTPUT | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MO | | | DAY | | | MO | | | DAY | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 |
| W | T | F | 0 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W | T | F | 0 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W | T | F | 0 | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W | T | F | 0 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W | T | F | 0 | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W | T | F | 0 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W | T | F | 0 | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W | T | F | 0 | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W | T | F | 0 | 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| W | T | F | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

# WEATHER AND STATION DATA CARDS

CARD WTA
WTB
WTC
TITLE CAN BE FILLED UP TO COLUMN 24.

CARD WTD STATION AND IDENTIFICATION

Input the name of the city and the name of the site. The date on which the work is being done is also input.

CARD WTE STATION AND SITE DATA

Weather Number- The distinct number alloted to each of the U.S. cities. (Available from Energy in Buildings Research Group or ESP manual.)

Site Number- Usually 1.

Site Data- The latitude, longitude, elevation (ft.), time-zone for U.S.A. zones.
Clearness numbers are normally set at 0.9 for both winter and summer for areas far from heavy industries.

Weather Year- The year for which the city's weather was taken.
No print schedule.

Daylight Saving Option- Set it to zero for automatic.

CARD WTF 01 PRINT OPTION FOR CERTAIN DAYS OF THE YEAR

The selected hours to be printed have value 1 and no print has value 0.

Print Option- Set at 1 for all data to be printed.

LA-7433-MS

Informal Report

100.

# PASOLE: A General Simulation Program for Passive Solar Energy



University of California

LOS ALAMOS SCIENTIFIC LABORATORY
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DEPARTMENT OF ENERGY
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# PASOLE: A General Simulation Program for Passive Solar Energy

Robert D. McFarland

# PASOLE: A GENERAL SIMULATION PROGRAM FOR PASSIVE SOLAR ENERGY

by

Robert D. McFarland

## ABSTRACT

The PASOLE computer program was developed to do simulations of passive solar heated buildings. Modeling is done using a general thermal network method that allows for heat sources and thermal storage. Sun position equations are used with a global-to-direct solar radiation correlation to develop solar heat sources from measured insolation data. Models of a particular class of south-mass-wall passive buildings have been developed and are described in this report.

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## INTRODUCTION

PASOLE (PAssive SOLar Energy) is a computer program that incorporates a general, thermal network solution of an interconnected system of uniform temperature regions with time-varying boundary conditions and heat sources. PASOLE was designed specifically for detailed analyses of passive solar heated structures and includes algorithms for calculating solar sources in a general way. Because of its generality, PASOLE can be used to simulate hybrid or active solar heating systems. The PASOLE format allows the user to describe the thermal network model by specifying nodes that represent finite regions, connections between these nodes, and parameters associated with the nodes and connections. These specifications are made in FORTRAN subroutines in the program. PASOLE is not a standard "user oriented" program; that is, to use the program for other than the specific models for which it is programmed, the user must have some knowledge of heat transfer principles and FORTRAN programming.

In describing the program, we will refer to a particular class of south-mass-wall (SMW) passive solar heating systems—the network models for which this version of PASOLE is programmed. Although PASOLE was not written specifically for these particular models, they have been used for extensive parametric analyses and serve as an example of how simulation models can be created. For these models, hour-by-hour simulations for one full year, using real weather data, take about 1 min of central processor (CP) time on the CDC 7600.

Most of the variables in the program are given in Appendixes A-C. The FORTRAN listing in Appendix D includes numerous comments. A sample output is given in Appendix E.

## THERMAL NETWORK MODEL OF PHYSICAL SYSTEM

The system's physical and environmental structure is represented by a network of N nodes, each representing a region of uniform temperature. Each node may be connected to any other node by a thermal conductance K, such that the rate of heat flow from node i to node j is linear, $Q_{ij} = K_{ij}(T_i - T_j)$. Each node may have a heat capacitance M and a heat source rate E. The source rate E may be a linear function of the node temperature $E = S + B \cdot T$.

The heat balance at any given node i at time t is

$$\sum_{j=1}^{N} K_{ij}\,(T_i - T_j) + M_i\,(dT/dt)_i = S_i + B_i T_i\,, \tag{1}$$

where j denotes each of the other nodes in the network system. Many of the $K_{ij}$'s usually are zero, but $K_{ij}$ is always zero for $j = i$. Many nodes have no heat source term ($S_i = B_i = 0$) and many have essentially no heat capacity ($M_i = 0$). When the node is massless its temperature is not directly dependent on its temperature history, so it requires a slightly different mathematical treatment, as shown below.

By rearranging Eq. (1) to obtain the time rate of node temperature change $(dT/dt)_i$, and by separating variables and integrating over the time interval from $t^\circ$ to t, we obtain the node temperature change over time increment $\Delta t$ by

$$T_i - T_i^\circ = \int_{t^\circ}^{t} \frac{S_i + B_i\,T_i}{M_i}\,dt + \sum_{j=1}^{N} \int_{t^\circ}^{t} \frac{K_{ij}}{M_i}\,(T_j - T_i)\,dt\,, \tag{2}$$

where the superscript zero denotes conditions at the "old" time, $t^\circ = t - \Delta t$.

The average values of the integrands are assumed to be a linear function of their values at times $t^\circ$ and t. Letting I be a general integrand

$$\int_{t^\circ}^{t} I\,dt = \bar{I}\,\Delta t\,, \tag{2a}$$

where $\bar{I} = f\,I + (1 - f)\,I^\circ$. Although f may be varied in the program and may take any value from zero to unity, a value of 0.5 usually is used because it is the most accurate and results in stable solutions.

Some nodes, such as outside air temperature, have "fixed" or known temperatures at a given time, whereas other nodes have "variable" or unknown temperatures that must be determined. Let NV be the number of variable-temperature nodes, NF the number of fixed-temperature nodes, and N the total number of nodes. By inserting the integrand approximation into Eq. (2) and collecting terms that contain the unknown $T_i$, the variable $T_j$'s, and the constant terms for each of the NV variable-temperature nodes, we obtain a set of NV linear equations with NV unknowns.

$$\sum_{j=1}^{NV} a_{ij} T_j = b_i \quad ; \quad i = 1, NV, \tag{3}$$

where

$$a_{ij} = -f K_{ij} \text{ for } j \neq i,$$

$$a_{ij} = M_i/\Delta t + f \left( \sum_{j=1}^{N} K_{ij} - B_i \right) \text{ for } j = i,$$

and

$$b_i = M_i \overset{\circ}{T}_i/\Delta t + f \left( S_i + \sum_{j=1}^{NF} K_{ij} T_j \right)$$

$$+ (1 - f) \left( M_i/\overset{\circ}{M}_i \right) \left[ \overset{\circ}{S}_i + \overset{\circ}{B}_i \overset{\circ}{T}_i + \sum_{j=1}^{N} \overset{\circ}{K}_{ij} \left( \overset{\circ}{T}_j - \overset{\circ}{T}_i \right) \right] .$$

For $M_i = M_i^\circ = 0$, $b_i$ reduces to

$$f \left( S_i + \sum_{j=1}^{N} K_{ij} T_j \right)$$

from Eq. (1), and f cancels out of the equation.

## SOLUTION

Temperatures are determined using Eq. (3) and a standard linear-equation solving technique. In this case the Los Alamos Scientific Laboratory's (LASL) library routine LSS was used to solve the variable temperatures, after the values of the a and b arrays had been determined. Because many of the variables used to determine the a and b arrays can be functions of temperature, thus making the problem nonlinear, an iteration loop is provided at each time step to obtain temperature dependencies where the temperature determined from the previous time step is not satisfactory. This problem arises particularly for natural convection (thermocirculation or thermosiphon) connections and thermal radiation connections.

If the coefficients $a_{ij}$ in Eq. (3) are constant—meaning the conductances are constant—the set of linear equations can be solved at the beginning of the program run. This results in a set of coefficients $F_{ij}$, such that the node temperatures can then be determined by

$$T_i = \sum_{j=1}^{NV} F_{ij} b_j ; \; i = 1, NV, \tag{4}$$

where the b arrays are as described in Eq. (3).

Use of this option can reduce computation time considerably for models with numerous nodes. In PASOLE, four sets of $F_{ij}$'s are calculated — for daytime or nighttime operation with a fixed or floating "control node" temperature.

## CONTROL TEMPERATURE

A particular temperature, such as room temperature, is monitored by a control node to maintain it within prescribed bounds. At present, only one control node is allowed. When this temperature is within the prescribed bounds, the control node is a variable-temperature node and no auxiliary heat source is required. When the control node temperature goes beyond a temperature bound during a time increment, the control temperature is fixed at the bound and an auxiliary heat source is calculated to maintain that temperature.

$$E_{aux} = \sum_{j=1}^{N} K_{ij} (T_i - T_j) - S_i - B_i T_i \, , \qquad (5)$$

where $T_i$ is the fixed bound temperature of the control node. In some models, the thermal conductance value of a connection to the control node can be varied within certain bounds (such as for proportional control dampers). This variability reduces or eliminates the need for an auxiliary heat source to maintain a control node temperature bound.

When the operating mode of the control node changes during the time step, the time step is subdivided and two or more calculations are made. Running sums of positive (source) and negative (sink) auxiliary heat sources are made. The sink (cooling) calculation is divided further into "ventilation" and "auxiliary" cooling, depending on whether the cooling occurs when the outside air temperature is below or above the control node upper bound temperature.

Running sums also are kept of the total heat into and out of individual nodes, the total node heat source and sink other than auxiliary, and total connection heat flows. For bookkeeping purposes the auxiliary heating or cooling of the control node is not combined with any other sources for that node.

## THERMAL CONNECTIONS

The most common thermal connection is the "UA" type

$$K_{ij} = U_k A_k \, , \qquad (6)$$

where $U_k$ is the overall heat transfer coefficient for connection k between nodes i and j, and $A_k$ is the heat transfer area of connection k. Many models have an advection connection that results from thermocirculation. The algebraic form of this connection conductance depends on the assumed temperature distributions in the legs of the circulation path and the relation between the temperature distributions and the temperature of the nodes that represent these legs. A common example is a Trombe wall collector that has an advection connection between the room and the heated air space between the wall and glazing. If it is assumed that the temperature distribution in the air space is linear, such that the air space node is at the arithmetic average of the inlet and outlet temperatures, and that the room air is fully mixed, the thermal conductance is given by $K_{ij} = 2\rho C_p \mathring{v}$, where $C_p$ is the air specific heat, $\rho$ is the air density, and $\mathring{v}$ is the volumetric air flow rate. Because the value of $\mathring{v}$ depends on the average air column temperatures, the thermal conductance is highly temperature dependent and iterations are required.

In the example model for a Trombe wall, the thermocirculation flow is calculated by

$$\mathring{v} = C_d \, A_v \, \sqrt{gH \, \Delta T/\bar{T}} \, , \tag{7}$$

where

$C_d$ is the vent discharge coefficient—taken to be 0.8,
$A_v$ is the area of one row of thermocirculation vents—top or bottom (assumed to be the same),
$g$ is the acceleration due to gravity,
$H$ is the air column height,
$\Delta T$ is the difference between the average temperatures of the wall/glazing air space and the room behind the wall, and
$\bar{T}$ is the average absolute temperature of the air space.

Equation (7) was derived by considering a driving force caused by the density difference between the two air columns and a flow resistance from two rows of vents in series, assuming the vents are the dominant resistance to air flow. The equation must be modified if there is another significant flow resistance, such as that to flow in the wall/glazing air space.

For problems involving one-dimensional transient conduction, such as in thick masonry mass walls, an adequate model can be made using several internal nodes in series, in which each node has a part of the total mass associated with it, and massless nodes on each surface. The nodes are connected by appropriate conduction UA values in the direction of heat flow. Other schemes in which each node has some mass associated with it may also give good results.

## INSOLATION

Any node may have several solar heat sources with various insolation areas, glazing tilts and azimuths, number and thickness of glazings, and solar absorptivites. In some cases, the applicable external insolation is read directly from the weather data file; in other cases, the weather data insolation is for a horizontal surface and a correction to the insolator orientation is required. Also required are estimates of reflected insolation and glazing transmission. The equations used to determine the insolation on an internal solar collector surface are given in Appendix A (most of the equations are from Ref. 1). The solar sources are added to other heat sources that have been specified for that node. The solar source for node i is calculated by

$$S_i = \mathrm{QTRAN \cdot AGLZ \cdot ALFA} \, , \tag{8}$$

where QTRAN is the solar flux transmitted through the glazing, AGLZ is the area of absorbing surface associated with node i, and ALFA is the solar absorbtivity of the surface. Solar radiation not absorbed by the surface is assumed to be lost; that is, internal reflections are not accounted for.

In the present PASOLE model, glazings of the primary solar source are represented by nodes. These nodes are given heat sources equal to the solar radiation absorbed by the glazing. The model could be expanded to allow for heat source nodes in the glazings of all solar sources.

## PHASE-CHANGE MATERIALS

Because temperature is the primary dependent variable, it is not convenient to handle heat-of-fusion as an isothermal enthalpy change. Problems involving phase-change materials have been solved by representing the heat-of-fusion as an increase in heat capacity over a given temperature range of about 10 to 20°C. For these problems the heat capacitance becomes a temperature-dependent parameter.

## PROGRAM STRUCTURE

PASOLE consists of a main program, seven subroutines, and one function (Fig. 1). All but one (COLLECT) of the subroutines are called directly by the main program. In addition to the PASOLE subroutines, several routines in the LASL computer library also are called by the main program.

Three time step loops are set up in the main program. The outer loop advances the month, the next loop advances the day of the month, and the inner loop advances the basic time step—usually 1 h. Another loop inside the inner time step loop is used for iterations, if required, for temperature dependence of the coefficients. Coefficients $a_{ij}$ and $b_i$ of Eq. (3) are computed inside the iteration loop. Equation (3) is solved using the LASL library routine LSS, or the temperatures are determined directly by solving Eq. (4). If any of the calculated node temperatures deviate from their previous iteration value (or from the previous time step, if the first iteration) by more than the specified value of TOLT, another iteration is made using the calculated temperatures as the new values. The iteration process continues until convergence is reached or until ITMAX iterations have been made. If convergence is not reached the run is not stopped, but the output counter KERR is advanced by one.

If the control node changes operating mode (from fixed to variable temperature, or vice versa) during a time step, the basic time step is divided into two or more smaller time steps, but no new solar/weather data are obtained.

At the end of each time step, heat flow sums are updated, variables are set for the next time step, and film file variables are set if graphic output is to be obtained. After all the time step loops are completed, the summary output is made. For parametric studies the entire program is put in a "problem" loop, in which specific parameters are varied.

## SUBROUTINES

The data required to run the problem and the parameters (Appendix B) that describe the model structure are set in subroutine INDATA. We also could use INDATA to read data from cards or from another file. All data written into INDATA are given in FORTRAN. Except for a block of default values at the beginning, INDATA probably would be changed completely for each different model.

Preliminary calculations are done in subroutine PRIME, using the data supplied in INDATA. Included in these calculations are the setting up of arrays of fixed- and floating-temperature nodes and the determination of the coefficients $F_{ij}$ of Eq. (4), if applicable.

Subroutine DAYLY is called once each time through the day loop. Here, the daily weather data are read from a data file or are calculated. In addition, the solar declination and extraterrestrial normal solar flux are computed for the current day. Weather data required are the

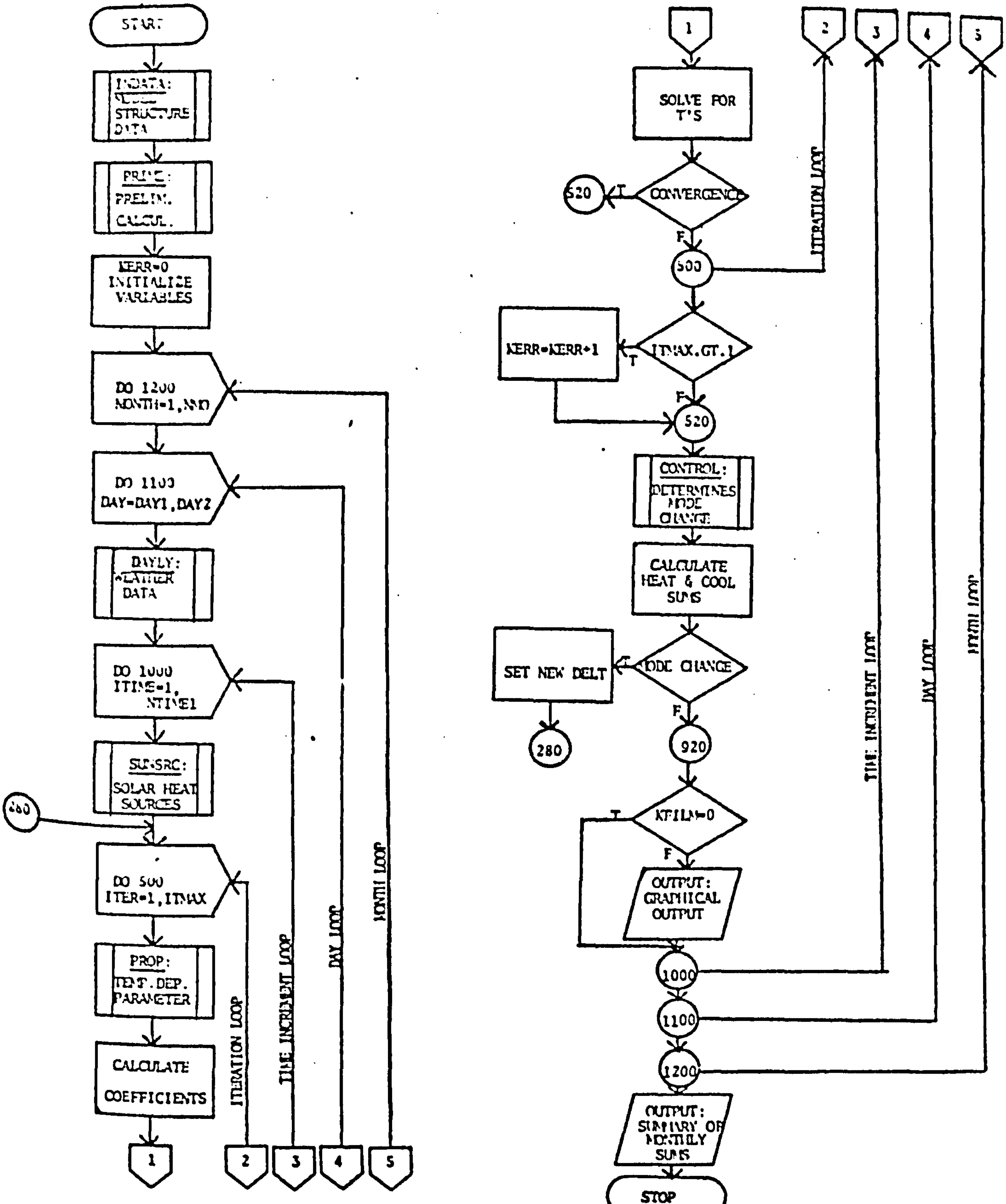


*Fig. 1.*
***PASOLE main program.***

total solar radiation flux on a known tilt (QHD) and the ambient air temperature (TAD). Also useful is the wind velocity (VELD). If there are fixed-temperature nodes other than the outside ambient, DAYLY is a convenient place to enter the temperature data for these nodes. Because weather data formats are different, this subroutine probably will have to be adapted to the particular data set being used.

SUNSRC calculates the heat sources from solar radiation absorption. Most of the equations in Appendix A are solved by SUNSRC. If the solar radiation measurements read in DAYLY are not taken on the horizontal plane, the subroutine COLLECT is called. COLLECT solves the Boes[2] correlation backwards; that is, it obtains the equivalent total horizontal radiation from the given measured radiation, the tilt (TILTC), and azimuth (AZIMC) of the measuring surface and the assumed diffuse ground reflectance (RHOC) pertaining to the measurement. The computed total horizontal radiation is then used to proceed with the calculations. Different optical systems than those assumed here (for example, one with internal reflections) would require changes in SUNSRC.

Model structure parameters that should be furnished by INDATA, but that are temperature and/or time dependent, are calculated in subroutine PROP, which is inside the temperature iteration loop. PROP is called just before the solution of Eq. (3) for node temperatures is obtained. This subroutine, like INDATA, probably will require changes for each different model.

Subroutine CONTROL determines whether a change has taken place in the operating mode of the control node. If a change has taken place the flags KICHNG and KIC are set, the fixed and variable node number arrays are adjusted, the time at which the node change occurs is determined, and temperatures at this time are calculated by linear interpolation. A new time increment is then determined for the remainder of the original time increment.

Descriptions of the variables found in the common blocks are given in Appendix C.

## COMPUTER SYSTEM REQUIREMENTS

Most of the LASL library routines, such as DATE1, CLOCK1, LSS, SPLOT, PLOT, and DLCH, will have to be replaced by local equivalents. DATE1 and CLOCK1, which merely return real date and time values for output, could be eliminated. SPLOT, PLOT, and DLCH are used to make SC-4020 CRT files for graphic output. If no equivalent routines exist or if graphic output is not required, that section of the program may also be eliminated. The routine LSS, called from the main program and from the subroutine PRIME, is used to solve the set of linear equations, Eq. (3), for the $T_j$'s given the coefficients $a_{ij}$ and $b_i$. Any computer facility of reasonable size should have software equivalent to LSS.

PASOLE requires a field length of 57 000 octal words for compilation and 122 000 octal words at execution including all library routines. No attempt has been made to minimize the core memory. The problems shown in Appendix E and in Figs. 2 and 3 require 4 to 5 min of CP time on a CDC 6600, or about 1 min on a CDC 7600, for a yearly calculation. Using the linearized method of Eq. (4), the execution time is reduced to about 1.5 min on a CDC 6600.

The loaders used at LASL automatically clear the registers, a feature used in PASOLE programming. Not all computer systems are set up this way, so it may be necessary to make special provisions to clear the registers. There are other differences between the CDC FORTRAN and other computer systems, such as multiple replacement statements and packed FORTRAN.

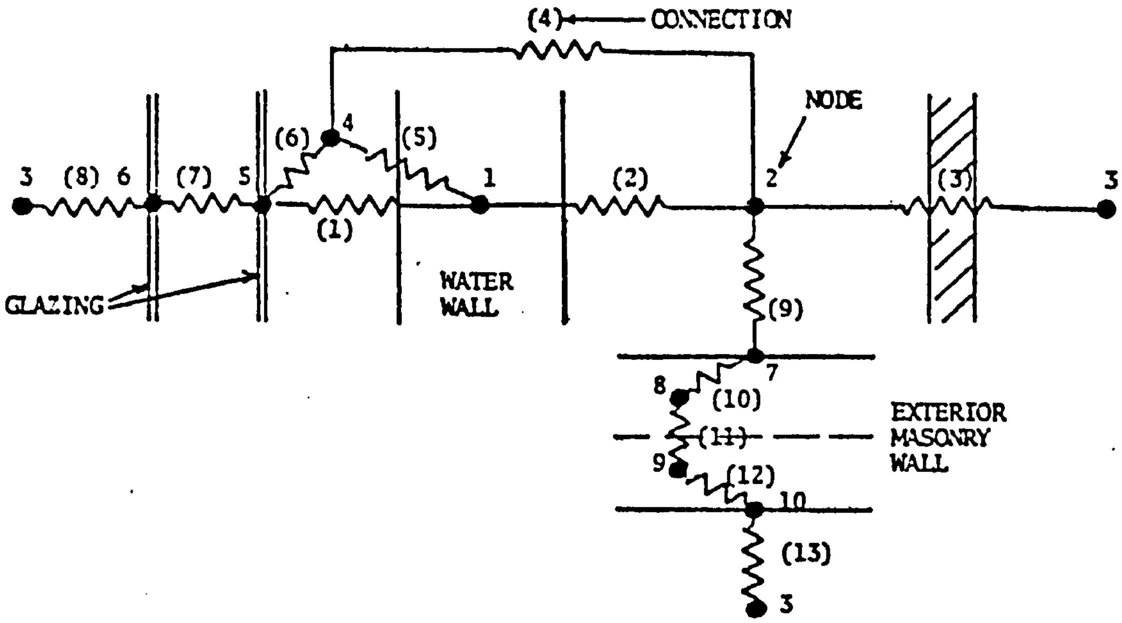


*Fig. 2.*
*Water wall model with massive exterior wall (KWALL = 1, NSGW = 2).*

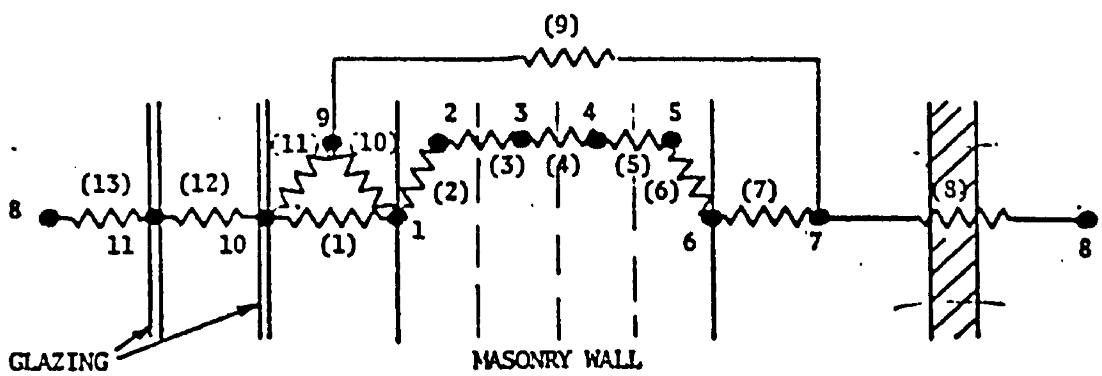


*Fig. 3.*
*Masonry wall model (KWALL = 2, NSGW = 0).*

## MODELING RESTRICTIONS

For simulations in the southern hemisphere, changes to the solar angle and time equations are required. There are no restrictions on initial temperature conditions, but a small heat balance error will be observed if the initial temperatures are not in equilibrium. The initial value of the ambient temperature(s) is set to the first weather data values in SUNSRC.

The number of nodes is now limited to 50 because of dimensions. If more detail is required, a different type of simulation program probably would be better suited. The computer time required is approximately proportional to the square of the number of nodes. A model with 30 nodes takes about 40 min of CP time on the CDC 6600 for a yearly hour-by-hour calculation. This time could be reduced considerably, however, if the linearized calculational procedure, Eq. (4), could be used.

## EXAMPLE MODELS

Built into subroutines INDATA and PROP of the present PASOLE version are two types of south-mass-wall (SMW) passive solar heating systems: (1) Water wall, in which the thermal storage and absorber wall are assumed to be isothermal and, therefore, representable by a single node, and (2) Trombe wall, in which the transient conduction through the SMW is modeled by several nodes in series assuming the heat flow is one dimensional. Figures 2 and 3 show the thermal network representation of these two types of SMW systems. Wall type is selected by setting the flag KWALL to 1 for a water wall and to 2 for a Trombe wall. Thermocirculation of warm air from the wall/glazing air space into the interior space is controlled by the flag KVENT, which is set to 0 for no thermocirculation, 1 for unlimited thermocirculation, 2 for backdraft prevention, and 4 for thermostatic control of the air flow. The number of glazings may be varied by changing the NGL value. The number of segments in the Trombe wall may be varied by changing the NSEG value.

The basic models have heat capacitance associated only with the SMWs. However, if the parameter NSGW is nonzero, an additional heat flow path is modeled through NSGW segments of a massive external wall, as shown in Fig. 2. This one-dimensional heat flow path, like that through the Trombe wall in Fig. 3, consists of several internal nodes that have the wall mass associated with them and massless nodes on the surfaces.

Parameters peculiar to these models and used only in INDATA and PROP are explained in the Appendix D program listing. The INDATA listing in Appendix D shows the first block of data is the set of default values for various "Program Variables." Here, program variables are defined as those set in INDATA and PROP that are needed to run the program—largely those listed in Appendix A. "Model Parameters" are defined as those used strictly in INDATA and PROP to set up the specific model, that is, to calculate values of the program variables.

After default values are set, the specific model programming begins with the setting of values for the model parameters. These values are most often changed when making parametric studies with the model. More model parameters are set further down for each wall type. Program connection parameters and node parameters then are evaluated using a methodology developed for these models. Next, constants used in PROP to evaluate temperature-dependent conductances are calculated.

The optional massive exterior wall is modeled for NSGW > 0 by adding nodes and connections to those set above. Next is a section for linearizing the model completely, if so desired, by calculating effective constant conductances for all connections. This linearization must be done if the simplified calculation (KCALC = 2) method is to be used, as explained in PRIME.

A provision for an outside insulation node on the SMW is used mostly for nonglazed south wall calculations. Finally, an output listing is made for many of the model parameters and resulting program variables.

In subroutine PROP the volumetric thermocirculation flow rate is calculated for KVENT nonzero using the previously calculated temperatures, after which conductances based on this flow rate are computed. Radiation and convection conductances between glazings, wall, air space, and outside air are calculated, again using the temperatures obtained from the previous iteration. The final section of PROP, which calculates values of program variables U, COND, and SCON, should be retained regardless of the model chosen. Even when all conductances are constant, these last calculations are made in PROP. Only the night (UN) and day (UD) values of conductance are set before these last calculations are made.

## SAMPLE OUTPUT

Appendix E shows output listings obtained from running the Appendix D program with the specific model parameters of Figs. 2 and 3 and using Los Alamos weather data beginning September 1, 1972. The first line of each listing in Appendix E gives real time and date, and the second line gives the model starting date. Parameter values given for "conductance connections" are connection number J; node numbers I1 and I2 (I1CON and I2CON) connected by connection J; and UD (day) and UN (night) values of conductance in Btu/h-°F-ft² consistent with ACON, which is the connection heat transfer area per unit SMW glazing area. Positive heat flow in connection J is from node I1 to node I2. Some of the conductances are shown as zero in the listings. The zero value usually means that the conductances are temperature-dependent and have not been calculated in INDATA.

Ambient temperature node and solar heat source information is given next. Following that is a block of integers and a block of real variables, which are a combination of program variables and model parameters whose names correspond to those defined in Appendixes B, C, and D. Except for the first line in the listings, the information is generated in INDATA when the flag KHEDPR is nonzero.

The summary table, always generated at the end of the problem in the main program, gives monthly totals.

DEGDAY - heating degree days
QOUT - heat loss back through SMW glazing
QHEAT - auxiliary heat required by the control node
QCOOL - total cooling required by the control node
QSOLAR - solar radiation absorbed in primary solar source
QLOAD - building heat load for other than SMW
QACL - auxiliary cooling required
QSINC - solar radiation incident on glazing of SMW
PCTSOL - percentage of solar heating defined by PCTSOL = 100 (1-QHEAT/QLOAD).

Headings given in the summary table are MTIME: total number of basic time increments (hours in this case); NSTEP: total number of time steps calculated; NCALC: total number of temperature solutions (including iterations); and KERR: number of convergence failures.

If IPRSM is nonzero, tables of the individual node and connection heat flow sums are printed. These sums are defined in Appendix C. Heat flows are given in Btu/ft² of SMW glazing.

In addition to the printed output, graphic output can be obtained using LASL library routines. Graphic output is generated starting when DATE is equal to IO1 through the day before IO2. Examples of plots for the model of Fig. 3 are shown in Appendix E (Figs. E-1 and E-2) for the same Los Alamos weather data as above, December 31, 1972, through January 6, 1973: (IO1 = 123172, IO2 = 10773). Figure E-1 shows the time variation of the temperatures of nodes 1, 6, 8, and 7. Figure E-2 shows the rate of solar radiation absorption in node 1 (the primary solar heat source), the rate of heat flow through connection 8 (the heat load), the total heat flow into the room through connections 7 and 9, and the total heat loss from the south side through connections 1 and 11.

Further results obtained using PASOLE may be found in Refs. 3 and 4.

## ACKNOWLEDGMENTS

The idea for a simulation program of this type was J. D. Balcomb's. J. C. Hedstrom wrote a preliminary one-mass-node simulation program. Robert Sutton of the Tasmanian College of Advanced Education, Robert Jones of the University of South Dakota, and William Wray of LASL made helpful suggestions arising from their development of PASOLE models for particular applications.

## REFERENCES

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2. E. Boes, "Estimating the Direct Component of Solar Radiation," Sandia Laboratories report SAND-75-0565 (November 1975).

3. R. P. Stromberg and S. O. Woodall, "Passive Solar Buildings: A Compilation of Data and Results," Sandia Laboratories report SAND-77-1204 (August 1977).

4. J. D. Balcomb and R. D. McFarland, "A Simple Empirical Method for Estimating the Performance of a Passive Solar Heated Building of the Thermal Storage Wall Type," Proc. 2nd Nat. Passive Solar Conf., Philadelphia, PA, March 16-18, 1978.

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## APPENDIX A
## EQUATIONS FOR SOLAR RADIATION

1. Solar declination (deg)†
   DEC = 23.279 * cos [30 * (MO − 1 + DAY/32 − 5.7)],
   where MO = month of year (MO = 6 for June, etc.) and
   DAY = day of month.

2. Extraterrestrial normal solar radiation†
   QSP = A1 − A2 * sin [360 * (272.1 + IDAY)/365],
   where A1 = 426.98, A2 = 13.50 for QSP in Btu/h-ft$^2$,
   A1 = 1346.1, A2 = 42.56 for QSP in W/m$^2$, and
   IDAY = day of year.

3. Equation of time (EOT) is given in tabular form, one value per month (min)

| | | | | | | |
|---|---|---|---|---|---|---|
| MO | 1 | 2 | 3 | 4 | 5 | 6 |
| EOT | −11.2 | −13.9 | −7.5 | 1.1 | 3.3 | −1.4 |
| MO | 7 | 8 | 9 | 10 | 11 | 12 |
| EOT | −6.2 | −2.4 | 7.5 | 15.4 | 13.8 | 1.6 |

†Curve fit of data in Ref. 2 by J. C. Hedstrom.

4. Solar time (h)
SUNTIME = TIME + EOT/60 − DLONG/15 − 0.5,
where TIME = local standard time, and
DLONG = difference between local longitude and standard time meridian (deg).
(0.5 is subtracted when insolation data are averaged over the preceding hour.)

5. Hour angle (deg)
HR = 15 * (12 − SUNTIME)

6. Critical hour angle (hour angle for which solar azimuth is 90°)
COS(HRCRIT) = TAN (DEC)/TAN(LAT)
with constraint that 0 ≤ COS(HRCRIT) ≤ 1.

7. Sun altitude (deg)
SIN(ALT) = COS(LAT)*COS(DEC)*COS(HR)+SIN(LAT)*SIN(DEC),
where LAT = latitude (deg).

8. Sun azimuth (deg)
SIN(AZI') = COS(DEC)*SIN(HR)/COS(ALT)
AZI' will always be between −90° and +90°.
To find the true value of the azimuth, AZIM
If |HR| ≤ HRCRIT, AZIM = AZI', and
if |HR| > HRCRIT, AZIM = (180−|AZI'|) * AZI'/|AZI'|.

9. Boes correlation[2] for direct normal and diffuse radiation measurements
   (a) PP = QH/[QSP*SIN(ALT)],
   where QH is total horizontal radiation.
   (b) FQDN = 1.79*PP − 0.55 with constraint
   that 0 ≤ FQDN ≤ 1.0.
   (c) QDN = FQDN*QDNMAX,
   where QDN = direct normal radiation and
   QDNMAX = 1000 W/m² = 317.2 Btu/h-ft².
   (d) QDIF = QH − QDN*SIN(ALT),
   where QDIF = sky diffuse radiation.

10. Wall/solar azimuth (deg)
GAM = AZIM − WAZI,
where WAZI is the wall azimuth; 0 when facing south and positive when facing east of south.

11. Wall/solar angle of incidence (deg)
COS(INC) = COS(ALT)*SIN(TILT)*COS(GAM) + SIN(ALT)*COS(TILT), where TILT is wall tilt from horizontal—positive toward south, and 0 ≤ INC ≤ 90°.

12. Radiation incident on wall from specular reflector. The equations are only for a horizontal reflector adjacent to a vertical wall. East-west dimensions of wall and reflector assumed equal. See also item 14.
   (a) RLEFF = COS(GAM)/TAN(ALT).
   If RLEFF > RLNGTH, RLEFF is set equal to RLNGTH, where RLNGTH is the ratio of the reflector length (N-S) to the wall height.

(b) DWOW = RLEFF*TAN(GAM)/ASPRAT, where ASPRAT is the ratio of the reflector width (E-W) to its length (N-S).

(c) ASR = RLEFF*(1-DWOW/2) if DWOW ≤ 1,
ASR = 0.5*ASPRAT/TAN(GAM) if DWOW > 1.

(d) QINSR = QDN*ASR*RHOSR*SIN(ALT), where QINSR = reflected radiation incident on wall, RHOSR = reflectivity of reflector.

13. Shading from overhang†
AFACT is the ratio of direct normal radiation incident on wall with overhang to that without overhang (Fig. A-1).
AFACT = 1 − [OHANG*TAN(BEFF) − OSEPR]/[SIN(TILT) + COS(TILT) *TAN (BEFF)]
Constrained: 0 ≤ AFACT ≤ 1, where TAN(BEFF) = TAN(ALT)/COS(GAM).

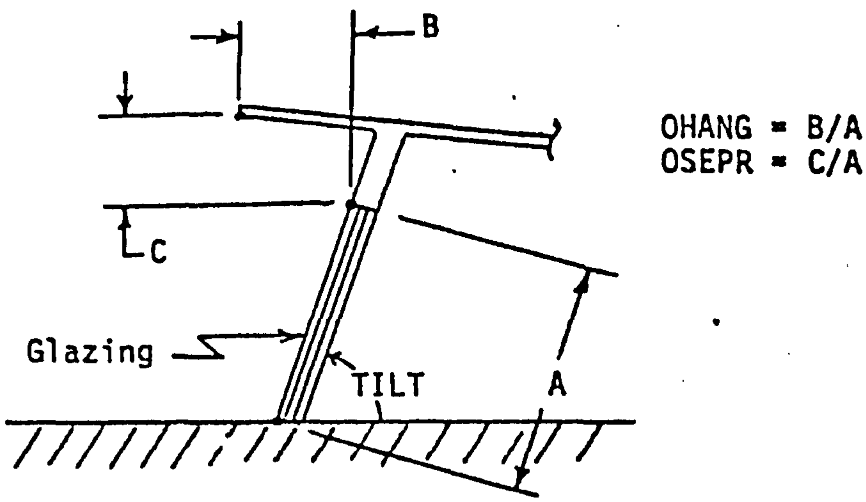


*Fig. A-1.*
*Overhang geometry.*

14. Total radiation incident on wall (collector)
QINC = QINDN + QINSR + QINDF + QINRF.

(a). QINDN is incident direct radiation
QINDN = QDN*AFACT*COS(INC).

(b) QINSR is incident reflected direct radiation (see item 12.d).

(c) QINDF is incident sky diffuse radiation
QINDF = QDIF*[1 + COS (TILT)]/2
(assuming infinite horizon).

(d) QINRF is incident reflected diffuse—includes diffuse ground reflection with infinite horizon and specular reflection of sky diffuse radiation.
QINRF = QH*RHO*(0.5*[1 − COS(TILT)] - FCSR) + QDIF*FCSR*RHOSR,
where RHO = diffuse ground reflectivity, FCSR = view factor between wall and specular reflector.
For this reflector model (see item 13)
FCSR = 0.5 (RLNGTH + 1 $-\sqrt{\text{RLNGTH}^2 + 1}$) approximately.

†Assumed to be infinite in E-W dimension (no end effects).

15. Transmission through glazings

QTRAN = [(QINDN + QINSR)*TRANS*GLABS + (QINDF + QINRF)*DTRANS*DGLABS]*TRCOAT

(a) TRANS = transmission resulting from surface reflection losses only

TRANS = 0.5*(T1 + T2),

where T1 = (1 − R1)/[1 + R1*(2*NGL − 1)],

T2 = (1 − R2)/[1 + R2*(2*NGL − 1)],

R1 = $[\mathrm{SIN(INC - AREF)/SIN(INC + AREF)}]^2$,

R2 = $[\mathrm{TAN(INC - AREF)/TAN(INC + AREF)}]^2$,

SIN(AREF) = SIN(INC)/RINDEX,

NGL = number of glazings in series, and

RINDEX = refractive index of glazing surfaces.

(b) GLABS = transmission resulting from absorption in the glazings only†

GLABS = EXP [−EX*TGLZ*NGL/COS(AREF)],

where EX = glazing material extinction coefficient, and

TGLZ = thickness of one glazing layer.

(c) TRCOAT = transmission of one glazing coating.

(d) TRANS and GLABS are for direct or beam radiation. An approximation to the transmission for diffuse radiation (DTRANS and DGLABS) is found by setting the angle of incidence (INC) to 60° in (a) and (b) above.

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†The variable GLABS in Appendix D is transmission for a single glazing layer.

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## APPENDIX B
## BASIC INPUT DATA

The basic input data must be entered into the program by the INDATA and PROP subroutines. Some parameters have internally set "default" values (shown in brackets). Use of the units must be consistent; either ASHRAE units (Btu, ft, h, °F) or S.I. units (W, m, s, °C) may be used with no significant changes. Frequently, many of the data are calculated from other input data in the subroutine INDATA, which is executed at the beginning of the problem. Some of the data (such as U values) may vary during the problem. In this case the data are recalculated in the subroutine PROP, which is within the time and iteration loops.

(A) Nodes (I)—I values not necessarily contiguous, but max I must be ≤ NMAX, which is currently 50.

KF(I): 0 for no node
1 for variable-temperature node [0]
2 for fixed-temperature node

T(I): Node temperature—initial values must be specified for all nodes. For fixed-temperature nodes, T(I) must be specified for all time steps.

CPM(I): Mass*heat capacity [heat capacitance, M in Eq. (1)]

S(I) Heat source = S(I) + SP (I)*T(I) [0]

SP(I) See Eq. (1)

(B) Connections (J)—J values should be contiguous starting with 1.

NCONN: Number of connections (Js)

I1CON(J), I2CON(J): Nodes connected by thermal connection J

UD(J), UN(J): Day and night specific conductance values of connection

ACON(J): Heat flow area of connection

U(J) is set to UD(J), if TMORN < TIME < TEVEN; UN(J) otherwise.
Then the conductance is COND (I1,I2) = U(J)*ACON(J),
where I1=I1CON(J), 12 = I2CON(J).

(C) Solar heat sources

| | | |
|---|---|---|
| NJS: | Number of solar heat sources | |
| ISOL(J): | Node number of solar heat source J | |
| TILT(J): | Collector tilt angle from horizontal for solar heat source J (deg) | |
| WAZIM(J): | Collector wall azimuth of source J (deg) | |
| ALFA(J): | Receiver solar absorptivity for source J | |
| AGLZ(J): | Glazing area for source J | |
| NGLZ(J): | Number of glazings in series for source J | |
| OHANG(J): | Overhang divided by glazing height (see Fig. A-1) | |
| OSEPR(J): | Overhang vertical separation divided by glazing height (see Fig. A-1) | |
| TGLZ(J): | Glazing thickness (feet or meter per layer) | |
| DABS(J): | Glazing diffuse absorptivity per layer | |

(D) Ambient temperature nodes

| | | |
|---|---|---|
| NJA: | Number of ambient temperature nodes | |
| IAMB(J): | Node number of Jth ambient temperature node | |

(E) Integers

| | | |
|---|---|---|
| IC: | Node number of control node | |
| IDPERYR: | Number of days per year | [365] |
| INDATE: | Initial date for which calculations start—of form MMDDYY, where MM is month, DD is day of month, YY is year | |
| IO1, IO2 | Beginning and ending dates of hourly print and film plots (IO2 is day after last day) | [0] |
| IPRSM: | Nonzero for print of all heat flow sums | [0] |
| ITMAX: | Maximum number of iterations per time step | [1] |
| KAUXCL: | = 0 for no auxiliary cooling (that is, no cooling when TAMB > TCMAX)<br>≠ 0 for auxiliary cooling | [1] |
| KCALC: | 1 for standard solution [Eq. (3)]<br>2 for simplified solution [Eq. (4)]<br>see comments in PRIME | [1] |
| KCONU: | 0 for variable conductances<br>1 for constant conductances<br>see comments in PRIME | [0] |
| KCTY: | Flag for weather data format (see subroutine DAYLY) | |
| KDATA: | = 0 for daily data (ambient temperature, wind velocity, solar radiation) read from tape (TAPE1)<br>≠ 0 for data from other source | [0] |

| | | |
|---|---|---|
| KDELT: | = 0 for no subdividing of basic time increment | |
| | ≠ 0 standard subdividing | [1] |
| | see comments in PRIME | |
| KFILM: | = 0 for no film plots | [0] |
| | ≠ 0 film plots | |
| KHEDPR: | = 0 for no printout of INDATA information | [1] |
| | ≠ 0 print | |
| MOSH1 } MOSH2 } | Beginning and ending months of summer period when night insulation operation is reversed† | [13, 0] |
| NDAY1: | Number of sequential daily calculations if < NDAY (MO) | [32] |
| NDAY(MO): | Number of days in month MO [set in data statement—if IDPERYR = 366, NDAY(2) is reset to 29] | |
| NHOUR: | Number of time increments on each film plot frame | [168] |
| NMAX: | Max number of nodes, that is, dimension | [50] |
| NMO: | Number of successive monthly calculations | |
| NTIME: | Number of time increments per day: $\Delta t = t/\mathrm{NTIME}$, where $\Delta t$ is time increment length and t is total number of time units per day (DELT1 and TPERDAY) | [24] |
| PRINTD: | = 0 no daily print | [0] |
| | ≠ 0 daily print | |
| PRINTH: | = 0 no hourly print | [0] |
| | ≠ 0 hourly print | |
| PRINTM: | = 0 no monthly print | [0] |
| | ≠ 0 monthly print | |
| UNITS: | = 1: Btu, h, ft, °F (ASHRAE units) | [1] |
| | = 2: J, s, m, °C (S.I. units) | |

(F) Real variables

| | | |
|---|---|---|
| ALAT: | Latitude of locality (deg) | |
| ASPRAT: | Specular reflector aspect ratio (E-W to N-S) | |
| AZIMC: | Pyranometer†† "wall azimuth" (deg) | [0] |
| DLONG: | Local longitude minus standard time meridan (deg) | |
| EX: | Extinction coefficient of glazing material ($ft^{-1}$) | [6.0] |
| FAC: | f in Eq. (2a) | [0.5] |
| FACI: | Same as FAC for heat flow integrals | [0.5] |
| FCSR: | View factor between collector and specular reflector | [0] |
| QDNMAX: | Maximum direct normal insolation in direct/diffuse correlation for measured data (Btu/h-$ft^2$ or W/$m^2$)[317.2 for UNITS = 1, 1000 for UNITS = 2] | |
| QHCONV: | Conversion factor from weather data insolation | |
| QICUT: | Value of incident solar radiation below which night insulation is applied | [$-1 \times 10^6$] |
| RDIFF(NGL): | Reflectance of glazings for NGL glazings in series for *diffuse* radiation (0.16, 0.24, 0.29, 0.33, 0.35) | |
| RESNI: | Resistance of night insulation on collector °F/(Btu/h-$ft^2$) or °C/(W/$m^2$) | |
| RHO: | Diffuse reflectivity of ground or other external reflector | [0.3] |
| RHOC: | Same for pyranometer†† | [0.3] |

†Night insulation is applied when TIME ≥ TEVEN and TIME ≤ TMORN for winter period.
††Pyranometer for which weather data insolation is given.

| | | |
|---|---|---|
| RHOSR: | Reflectivity of specular reflector | [0] |
| RINDEX: | Refractive index of glazings | [1.526] |
| RLNGTH: | Specular reflector length (N-S) divided by glazing height | [0] |
| SBCON: | Stefan-Boltzmann constant (1.7132 x $10^{-9}$ Btu/h-$ft^2$-°$F^4$ or 5.67 x $10^{-8}$ W/$m^2$-°$C^4$) | |
| TBASE: | Base temperature for heating degree-days (65°F or 18°C) | |
| TCMAXD: | Max allowable control node temperature for day | |
| TCMAXN: | Max allowable control node temperature for night | |
| TCMIND: | Min allowable control node temperature for day (°F or °C) | |
| TCMINN: | Min allowable control node temperature for night (°F or °C) | |
| TEVEN: | Time at which "night" starts | [17 h] |
| TILTC: | Tilt of pyranometer† (degree from horizontal) | [0] |
| TMORN: | Time at which "daytime" starts | [7 h] |
| TOLT: | Tolerance on temperature iteration (°F or °C) | [1.0] |
| TPERDAY: | Number of time units per day | [24 h/day or 86 400 s/day] |
| TRCOAT: | Transmission of coating on inner surface of inner collector glazing | [1.0] |
| TZERO: | Difference between zero and absolute zero on temperature scales | [460°F or 273°C] |

†Pyranometer for which weather data insolation is given.

## APPENDIX C
## PARAMETERS IN COMMON

All parameters in Appendix B are also in COMMON. Starred parameters must be generated in DAYLY (weather data). Routines in brackets are where parameter is calculated.

| | | |
|---|---|---|
| A(I,J) | Temperature coefficients in Eq. (3) | [MAIN] |
| B(I) | Source terms in Eq. (3) | [MAIN] |
| COND(I,J) | Conductance of connection between nodes I and J $K_{ij}$ in Eq. (1) | [PROP] |
| COSDEC | COS(DEC) | [DAYLY] |
| COSLAT | COS(ALAT) | [PRIME] |
| COSTC | COS(TILTC) | [PRIME] |
| DATE | Integer date of same form as INDATE (see Appendix B) | [DAYLY] |
| DAY | Index of day loop in main program (integer day of month) | [MAIN] |
| DAY1 | First day in day loop (integer) | [MAIN] |
| DAY2 | Last day in day loop (integer) | [MAIN] |
| DD | Heating degree days | [DAYLY] |
| DEC | Solar declination (deg) | [DAYLY] |
| DEGRAD | $\pi$/180—conversion from degrees to radians | [MAIN] |
| DELT | Current time increment | [MAIN] |
| DELT1 | Basic time increment | [PRIME] |

| | | |
|---|---|---|
| ERRT(I) | Deviation of node temperature between successive iterations | [MAIN] |
| FD(I,J,K) / FN(I,J,K) | Coefficients $F_{ij}$ in Eq. (4) for "day" and "night" K = 1 for IC a variable-temperature node; K = 2 for IC a fixed-temperature node | [PRIME] |
| FRAC | Fraction of DELT since beginning of time increment or last control mode change | [CONTROL] |
| FSGC | View factor between pyranometer and ground | [PRIME] |
| FSSC | View factor between pyranometer and sky | [PRIME] |
| HRCRIT | Hour angle at which azimuth is 90° | [DAYLY] |
| IAIR† | (For SMW models) node number of air in glazing/wall space | [INDATA] |
| IDAY | Day of year | [PRIME,MAIN] |
| INDAY | Initial day of month (from INDATE) | [PRIME] |
| ISOLX(IH)* | Weather data time offset (see equation for SUNTIME in Appendix D, subroutine SUNSRC) | [DAYLY] |
| ITIME | Index of time increment loop | [MAIN] |
| IXFILM | Index of film plot arrays | [MAIN] |
| JAIR† | Number of connection between IAIR and IC | [INDATA] |
| JCP† | Connection number of nonmass-associated load | [INDATA] |
| JCW† | Connection number of mass-associated load | [INDATA] |
| JWA† | Connection number between mass-wall surface node and IAIR. This is the first in a sequence of connections from the wall through the glazings to which glazing conductance calculations are keyed | [INDATA] |
| KCOOL | = 0 for no night insulation<br>= 1 for winter operation<br>= −1 for summer operation<br>(see MOSH1, MOSH2 in Appendix B) | [MAIN] |
| KIC | Control node mode indicator<br>−1 for T(IC) at TCMIN limit, QCIN > 0<br>0 for TCMIN < T(IC) < TCMAX, QCIN = 0<br>+ 1 for T(IC) at TCMAX limit, QCIN < 0<br>+ 2 for T(IC) fixed for all time (TCMIND = TCMAXD, TCMINN = TCMAXN) | [CONTROL]<br>[PRIME] |
| KICHNG | = 0 for no mode change<br>= for mode change | [CONTROL] |
| KND | = 1 for night<br>= 2 for day (TMORN < TIMEX < TEVEN) | [MAIN] |
| KSHUT | = KCOOL for night<br>= −KCOOL for day<br>Night insulation is used if KSHUT = + 1 | [MAIN] |
| KVENT† | = 0 for no thermocirculation<br>1 for unlimited thermocirculation<br>2 for thermocirculation with backdraft dampers<br>4 for thermocirculation with thermostatic control | [INDATA] |

†For SMW models.

| | | |
|---|---|---|
| KWALL[†] | = 1 for water wall model<br>= 2 for Trombe wall model | [INDATA] |
| LF(IF) | Array of fixed-temperature nodes | [PRIME] |
| LT(IT) | Array of all nodes | [PRIME] |
| LV(IV) | Array of variable-temperature nodes | [PRIME] |
| MO | Current month number (MO = 1 for January, etc.) The month loop index is MONTH, which always goes from 1 to NMO | [MAIN] |
| MO1 | Initial value of MO, from INDATE | [PRIME] |
| MTIME | Number of basic time increments from beginning of problem | [MAIN] |
| NERR | Number of nodes not converging | [MAIN] |
| NF | Number of fixed-temperature nodes | |
| NPR1,NPR2 | First and last problem numbers | [MAIN] |
| NPROB | Index of problem loop | [MAIN] |
| NT | Number of nodes, total | |
| NV | Number of variable temperature nodes | |
| PI | $\pi$ | [MAIN] |
| QACL | Integral auxiliary cooling of control node | [MAIN] |
| QAHT | Integral auxiliary heating of control node | [MAIN] |
| QC12(J) | Net heat rate through connection J [positive from node I1CON(J) to node I2CON(J)] | [MAIN] |
| QCIN | Heat source or sink applied to control node to maintain temperature limits | [MAIN] |
| QCINO | QCIN from previous time step | [MAIN] |
| QCINT | Integral of QCIN over one time step | [MAIN] |
| QCON(I) | Net heat rate conducted into node I | [MAIN] |
| QFACO(I) | Time rate of temperature change of node I, previous time step | [MAIN] |
| QHD(IH)* | Weather data insolation (pyranometer data) | [DAYLY] |
| QHZ | QHD(IH) converted to correct units | [SUNSRC] |
| QINC | Solar heat flux incident on collector (primary solar heat source) | [SUNSRC] |
| QSP | Normal, extraterrestrial solar radiation | [DAYLY] |
| QSRC(I) | Net heat source rate in node I | [MAIN] |
| QTRAN | Solar heat flux transmitted through collector glazing(s) | [SUNSRC] |
| QVCL | Integral vent cooling of control node | [MAIN] |
| QVHT | Integral vent heating of control node | [MAIN] |
| RCON(I)[†] | Array of constants generated in INDATA for use in PROP, or just for general use | [INDATA] |
| REMAIN | Remaining fraction of basic time increment | [CONTROL] |
| RHD(IH)* | A fourth weather data parameter (relative humidity in some cases) | [DAYLY] |
| SCON(I) | Sum of conductances (COND) of connections to node I | [PRIME, PROP] |
| SINDEC | SIN(DEC) | [DAYLY] |
| SINLAT | SIN(ALAT) | [PRIME] |

[†]For SMW models.

| | | |
|---|---|---|
| SINTC | SIN(TILTC) | [PRIME] |
| SQCON1(I), SQCON2(I) | Integrals of positive and negative values of QCON(I) over time | [MAIN] |
| SQC121(I), SQC122(I) | Integrals of positive and negative values of QC12(I) over time. | [MAIN] |
| SQSRC1(I), SQSRC2(I) | Integrals of positive and negative values of QSRC(I) over time. | [MAIN] |
| TAD(IH)* | Weather data—ambient temperature | [DAYLY] |
| TAMB | Ambient temperature | [SUNSRC] |
| TBAR | Daily average ambient temperature | [DAYLY] |
| TCMAX | Maximum allowable control node temperature | [MAIN] |
| TCMIN | Minimum allowable control node temperature | [MAIN] |
| TCOOL | Threshold ambient temperature above which any cooling of control node cannot be done by venting. Now set equal to TCMAX | [MAIN] |
| TIME | Time of day in consistent units | [MAIN] |
| TIMEX | Time of day in hours | [MAIN] |
| TMAX | Daily maximum ambient temperature | [DAYLY] |
| TMIN | Daily minimum ambient temperature | [DAYLY] |
| TO(I) | Node temperature from previous time step | [MAIN] |
| U(J) | Conductance per unit area of connection J | [PROP] |
| VELD(IH)* | Weather data—wind velocity | [DAYLY] |
| VOLF† | Thermocirculation volumetric flow rate | [PROP] |
| YR | Two-digit year number | [DAYLY] |

†For SMW models.

PASOLE2 LISTING.
FILE N$\underline{^{o}}$ 3 on TAPE TA 1219.
DSN = PASOLE2.

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C THIS VERSION OF PASOLE IS USER ORIENTED. THE ADDITIONS
C HAVE BEEN PUT IN BY L. SIMEZA. UNIVERSITY OF WINDSOR
C WINDSOR ONTARIO. SEPTEMBER 1981.
C THIS VERSION GETS ITS DATA FRO A PROSSESED WEATHER FILE
C IT ALSO OUTPUTS THE ACTUAL AMOUNT OF ENERGY INTO THE CONTROL
C NODE FROM THE VENTS AND THAT CONDUCTED THROUGH THE WALL.
C THIS IS GIVEN AS A MONTHLY SUMMARY . THIS VALUE CAN BE SUBTRACTED
C FROM THE HEATING DEMAND ON THE ASSUMPTION ALL HEAT INTO THE ROOM
C WILL BE CHANNELED TO HEAT OTHER ROOMS IF NECESSARY.
C --- IBM VERSION
C -- THIS VERSION DIFFERS FROM THAT IN LA-7433-MS AS FOLLOWS:
C --- VARIABLE & SUBROUTINE NAMES DO NOT EXCEED SIX CHARACTERS;
C --- MULTIPLE ASSIGNMENT STATEMENTS SEPARATED; A10 FORMAT SPECIFIC-
C --- ATIONS REPLACED BY A4 FORMAT CONVERSIONS; IMPLIED DO LOOPS IN DATA
C --- STATEMENTS REMOVED; VARIABLES IN LABELED COMMON ARE NOT DATA LOADED;
C --- FUNCTION NAMES ACOS & ASIN CHANGED TO ARCOS & ARSIN;
C -- (1) LINEAR SYSTEM SOLVING ROUTINE HAS BEEN CHANGED AND IS ATTACHED
C -- (2) FORTRAN HAS BEEN "UNPACKED" (ONE STATEMENT TO A LINE)
C -- (3) GRAPHICS ROUTINE CALLS HAVE BEEN REMOVED (THESE WERE LASL
C --     LIBRARY ROUTINES)
C -- (4) "CLEAR DAY" CALCULATIONS HAVE BEEN ADDED FOR INSOLATION (DAYLY)
C -- (5) HOLLERITH FIELD DELIMETERS HAVE BEEN REPLACED BY (N)H SPEC'S
C -- (6) VARIOUS OTHER CLEAN-UP OPERATIONS HAVE BEEN PERFORMED SUCH AS
C --     INITIALIZING VARIABLES, REMOVING SOME UNUSED VARIABLES, ETC.
C--(7) THIS VERSION NEEDS INPUT IN FORM GIVEN IN THE MANUAL AVAILABLE
C IN THE MECH. ENG. DEPT U OF W (BUILDING AND ENERGY RESEARCH GROUP)
      COMMON/BLAD1/NV,NF,NT,NMAX,KF(50),IC,LV(50),LF(50),LT(50),
     1 KICHNG,KIC,ITMAX,NERR,UNITS,KAUXCL,KCTY,KCALC,KDELT,KCONU
      COMMON/BLAD2/NTIME,MTIME,ITIME,DATE,DAY,DAY1,DAY2,NDAY(12),
     1 MO,MO1,YR,NMO,NDAY1,INDATE,IPRSM,KHEDPR
      COMMON/BLAD3/T(50),TO(50),CPM(50),S(50),SP(50),COND(50,50),
     1 SCON(50),QFACO(50),ERRT(50),FN(50,50,2),FD(50,50,2)
      COMMON/BLAD4/A(50,50),B(50),SQSRC1(50),SQSRC2(50),SQCON1(50),
     1 SQCON2(50),QVHT,QVCL,QAHT,QACL,QHZ,QINC,QTRAN
      COMMON/BLAD5/DELT1,DELT,TIME,SUMKT,QCIN,QCINO,FAC,FRAC,
     1 PI,TIMEX,DEGRAD,TBASE,DD,TMAX,TMIN,TBAR,FACI,REMAIN
      COMMON/BLAD6/QSRC(50),QCON(50),QC12(100),SQC121(100),
     1 SQC122(100),TCMIN,TCMAX,TCMINN,TCMIND,TCMAXN,TCMAXD,DTCOOL
      COMMON/BLAD7/TPRDAY,SBCON,TAMB,QCINT,PRINTH,PRINTD,PRINTM
      COMMON/BLAD8/IDAY,IDPRYR,INDAY,KDATA,QHCONV,ALAT,DLONG,
     1 RINDEX,TOLT,DEC,COSDEC,SINDEC,SINLAT,COSLAT,QSP
     2 ,HRCRIT,QICUT,TMORN,TEVEN,KSHUT,KCOOL,MOSH1,MOSH2
      COMMON/BLAD9/TAD(50),VELD(50),QHD(50),NJS,ISOL(15),
     1 TILT(15),WAZIM(15),AGLZ(15),NGLZ(15),NJA,IAMB(10),
     2 ALFA(15),OHANG(15),OSEPR(15),TGLZ(15),DABS(15)
      COMMON/BLAD10/QDNMAX,RDIFF(15),EX,RHO,TZERO,
     1 NCONN,I1CON(100),I2CON(100),U(100),ACON(100),UD(100),UN(100)
      COMMON/BLAD11/TILTC,AZIMC,RHOC,COSTC,SINTC,FSSC,FSGC,RESNI,
     1 JCP,KND,QDH(24),QFH(24)
      COMMON/TROMBE/VOLF,RCON(50),KVENT,IAIR,JAIR,RLNGTH,RHOSR,
     1 ASPRAT,FCSR,JWA,TRCOAT,IO1,IO2,KWALL,NHOUR,ULOAD,IDAT
C
      DIMENSION LDAY(2),QSUMM(12,20),MOY(12),SUMTOT(20)
C
      INTEGER DAY,DAY1,DAY2,YR,DATE,UNITS,PRINTH,PRINTD,PRINTM
```

```
C
      PRINT 2999
C
C----OBTAIN INPUT DATA
C THIS IS WHERE TAPE DATA CAN BE INPUT
      CALL INDATA
C----INITIAL CALCULATIONS
      CALL PRIME
      KERR=0
      KINC=0
      MTIME=0
      NCALC=0
      NSTEP=0
C
C

      QVHT=0.
      QVCL=0.
      QAHT=0.
      QACL=0.
      DD=0.
      DDH=0.
      QHSUM=0.
      QISUM=0.
      QLOAD=0.
      DO 220 I=1,NMAX
      SQSRC1(I)=0.
      SQSRC2(I)=0.
      SQCON1(I)=0.
      SQCON2(I)=0.
  220 CONTINUE
      DO 225 J=1,NCONN
      QC12(J)=0.
      SQC121(J)=0.
  225 SQC122(J)=0.
C -- FOR NDAY1 DAYS ONLY (NDAY1 LESS THAN 32)
      IFLG1=0
      IF(NDAY1.GE.32) GO TO 228
      IFLG1=1
      NMO=1
      LDAY(1)=INDAY+NDAY1-1
      IF(LDAY(1).LE.NDAY(MO1)) GO TO 228
      LDAY(2)=LDAY(1)-NDAY(MO1)
      LDAY(1)=NDAY(MO1)
      NMO=2
  228 CONTINUE
C
C
C----START TIME STEP LOOP
C
      MO=MO1-1
      DO 1200 MONTH=1,NMO
      MO=MO+1
      IF(MO.EQ.13) MO=1
      KCOOL=0
```

```
      IF(RESNI.LT.0.01) GO TO 237
      KCOOL=1
      IF(MO.GE.MOSH1.AND.MO.LE.MOSH2) KCOOL=-1
  237 CONTINUE
      DAY1=1
      IF(MONTH.EQ.1) DAY1=INDAY
      DAY2=NDAY(MO)
      IF(IFLG1.EQ.1) DAY2=LDAY(MONTH)
C
C----DAY LOOP
      DO 1100 DAY=DAY1,DAY2
C -- INITIALIZE TIME OF DAY - IF WEATHER DATA STARTS AT ONE TIME
C -- INCREMENT PAST MIDNIGHT THEN SET TIME TO ZERO
      TIME=-DELT1
C
      NTIME1=NTIME
      IDAY=IDAY+1
      IF(IDAY.GT.IDPRYR) IDAY=1
C
      CALL DAYLY
C
      DTWD=0.
      LPRNTH=0
      IF(DATE.EQ.I01.AND.PRINTH.EQ.1) LPRNTH=1
      IF(DATE.EQ.I02) LPRNTH=0
      IF(LPRNTH.EQ.0)GO TO 245
      PRINT 4003,DATE
  245 CONTINUE
C
C----TIME INCRIMENT LOOP
      DO 1000 ITIME=1,NTIME1

      LTIME=ITIME-1
      IF(LTIME.EQ.0) LTIME=NTIME
      MTIME=MTIME+1
      DELT=DELT1
      TIME=TIME+DELT
      TIMEX=TIME*24./TPRDAY
      KICHNG=0
      KND=1
      IF(TIMEX.GT.TMORN.AND.TIMEX.LT.TEVEN) KND=2
      KSHUT=-1
      IF(KND.EQ.1.AND.RESNI.GT.0.01) KSHUT=1
      KSHUT=KSHUT*KCOOL
      GO TO(250,255),KND
  250 TCMIN=TCMINN
      TCMAX=TCMAXN
      GO TO 260
  255 TCMIN=TCMIND
      TCMAX=TCMAXD
  260 CONTINUE
      TCOOL=TCMAX-DTCOOL
      TCMAX1=TCMAX
C
      CALL SUNSRC
```

```
C
      QHSUM=QHSUM+DELT*QHZ
      QISUM=QISUM+DELT*QINC
C
      IF(KAUXCL.EQ.0.AND.TAMB.GT.TCMAX) TCMAX=TAMB
      IF(KIC.EQ.-1) T(IC)=TCMIN
      IF(KIC.EQ.+1) T(IC)=TCMAX
      IF(KIC.EQ.2) T(IC)=TCMIN
      I280=0
  280 CONTINUE
      I280=I280+1
      LDELT=1
      IF(KDELT.EQ.0.AND.I280.EQ.2) LDELT=0
      IF(I280.LT.5) GO TO 283
      KINC=KINC+1
      LDELT=0
  283 CONTINUE
C----ITERATION LOOP FOR TEMPERATURE DEPENDENCE
      DO 500 ITER=1,ITMAX
      NCALC=NCALC+1
C----GET CPM,SP,COND,T(FIXED),SCON - COULD BE F(T)
      CALL PROP
      IF(MTIME.EQ.1) GO TO 800
C----CALCULATE COEFFICIENTS
      DO 400 IV=1,NV
      I=LV(IV)
      SUMKT=0
      FAK=FAC
      IF(CPM(I).LE.0.) FAK=1
      DO 300 JF=1,NF
      J=LF(JF)
  300 SUMKT=SUMKT+COND(I,J)*T(J)
      RAT=1.0
      IF(CPM(I).NE.0.) RAT=CPM(I)
      B(IV)=CPM(I)*TO(I)/DELT+FAK*(S(I)+SUMKT)+(1.-FAK)*RAT*QFACO(I)
      IF(KCALC.EQ.2) GO TO 400
      DO 320 JV=1,NV
      J=LV(JV)
      A(IV,JV)=-FAK*COND(I,J)
      IF(I.EQ.J) A(IV,JV)=CPM(I)/DELT+FAK*(SCON(I)-SP(I))
  320 CONTINUE
  400 CONTINUE
      IF(KCALC.EQ.2) GO TO 460
C
C----SOLVE EQUATIONS% SUMàA(I,J)*T(J)è=B(I) ; I=1,NV
C----FOR T(J) - ANSWERS IN B ARRAY
      CALL MCFLSS(NMAX,NV,A,B)

      NERR=0
      DO 440 IV=1,NV
      I=LV(IV)
      TGUESS=T(I)
      T(I)=B(IV)
      ERRT(I)=TGUESS-T(I)
      IF(ABS(ERRT(I)).GT.TOLT) NERR=NERR+1
```

```
 440 CONTINUE
     IF(NERR.EQ.0) GO TO 520
C
     GO TO 500
C
C -- SIMPLIFIED CALCULATION (SEE PRIME)
 460 CONTINUE
     IX=KF(IC)
     DO 480 IV=1,NV
     I=LV(IV)
     T(I)=0
     DO 480 JV=1,NV
     IF(KSHUT) 464,464,462
 462 T(I)=T(I)+FN(IV,JV,IX)*B(JV)
     GO TO 480
 464 T(I)=T(I)+FD(IV,JV,IX)*B(JV)
 480 CONTINUE
     GO TO 520
C
 500 CONTINUE
C----END OF ITERATION LOOP
     IF(ITMAX.GT.1) KERR=KERR+1
 520 CONTINUE
C
C----HEATING OR COOLING OF CONTRL NODE
     QCIN=0.
     IF(KIC.EQ.0) GO TO 560
     DO 540 IT=1,NT
     I=LT(IT)
 540 QCIN=QCIN+COND(IC,I)*(T(IC)-T(I))
     QCIN=QCIN-SP(IC)*T(IC)-S(IC)
     IF(KIC.EQ.2) GO TO 800
 560 CONTINUE
     IF(LDELT.EQ.0) GO TO 800
     NSTEP=NSTEP+1
     CALL CONTRL
     DELT=FRAC*DELT1
     IF(KDELT.NE.0) GO TO 800
     DELT=DELT1
     IF(KICHNG.EQ.0) GO TO 800
     GO TO 280
C
C----CALCULATIONS FOR OUTPUT, NEXT TIME STEP LOOP
 800 CONTINUE
C
     DO 808 J=1,NCONN
     QC120=QC12(J)
     I1=I1CON(J)
     I2=I2CON(J)
     QC12(J)=COND(I1,I2)*(T(I1)-T(I2))
     IF(MTIME.EQ.1) GO TO 808
     CALL SQF(QC12(J),QC120,FACI,DELT,SQC121(J),SQC122(J))
 808 CONTINUE
     IF(KAUXCL.NE.0) GO TO 806
     DDDH=DELT*(.5*(T(IC)+TO(IC))-TCMAX1)
```

```
      IF(DDDH.LT.0.) DDDH=0
      DDH=DDH+DDDH
  806 CONTINUE
      DO 900 IT=1,NT
      I=LT(IT)
      QSRCO=QSRC(I)
      QCONO=QCON(I)
      QSRC(I)=S(I)+SP(I)*T(I)

      QCON(I)=0.
      DO 820 JT=1,NT
      J=LT(JT)
  820 QCON(I)=QCON(I)+COND(I,J)*(T(J)-T(I))
      DEN=1.0
      IF(CPM(I).GT.0.) DEN=CPM(I)
      QFACO(I)=(QSRC(I)+QCON(I))/DEN
      TO(I)=T(I)
      IF(MTIME.EQ.1) GO TO 900
      CALL SQF(QSRC(I),QSRCO,FACI,DELT,SQSRC1(I),SQSRC2(I))
      CALL SQF(QCON(I),QCONO,FACI,DELT,SQCON1(I),SQCON2(I))
  900 CONTINUE
      IF(MTIME.EQ.1) GO TO 910
C----SUM HEATING, COOLING -- QV BY VENTILATION, QA BY AUXILIARY SYSTEM
      QCINT=DELT*(FACI*QCIN+(1.-FACI)*QCINO)
      IF(KICHNG.EQ.0.OR.LDELT.NE.0) GO TO 902
      QFRAC=REMAIN
      IF(KIC.EQ.0) QFRAC=FRAC
      QCINT=QCINT*QFRAC
      KICHNG=0
  902 CONTINUE
      IF(QCINT.GT.0.0.AND.TAMB.GT.TCMIN) QVHT=QVHT+QCINT
      IF(QCINT.LT.0.0.AND.TAMB.LE.TCOOL) QVCL=QVCL+QCINT
      IF(QCINT.GT.0.0.AND.TAMB.LE.TCMIN) QAHT=QAHT+QCINT
      IF(QCINT.LT.0.0.AND.TAMB.GT.TCOOL) QACL=QACL+QCINT
      IF(T(IC).GT.TAMB) QLOAD=QLOAD+DELT*ULOAD*(T(IC)-TAMB)
      IF(LPRNTH.EQ.0) GO TO 910
      PRINT 4000,TIME,ITER,I280,QCIN,(T(I),I=1,NT)
      PRINT 4001,(S(I),I=1,NT)
      PRINT 4002,(QC12(J),J=1,NCONN)
  910 QCINO=QCIN
      IF(KICHNG.EQ.0) GO TO 920
      DELT=REMAIN*DELT1
      GO TO 280
  920 CONTINUE
C
      DTWD=DTWD+T(1)-TAMB
C
 1000 CONTINUE
      IF(NTIME1.GT.0)DTWD=DTWD/NTIME1
C
      IF(PRINTD.EQ.0) GO TO 1100
      PRINT 3005,DATE,DAY,MO,QVHT,QVCL,QAHT,QACL,DD,QSP,DEC,DTWD
      PRINT 3006
      DO 1020 IT=1,NT
      I=LT(IT)
```

```
1020 PRINT 3007,I,SQSRC1(I),SQSRC2(I),SQCON1(I),SQCON2(I)
1100 CONTINUE
C
C -- SUMS FOR SUMMARY PRINT
C*********************************************
C
C
     M=MONTH
     MOY(M)=MO
     QSUMM(M,1)=DD
     QSUMM(M,2)=0
     QSUMM(M,2)=QSUMM(M,2)+SQC121(1)+SQC122(1)+SQC121(JWA+1)+
    1 SQC122(JWA+1)
     QSUMM(M,3)=QVHT+QAHT
     QSUMM(M,4)=QVCL+QACL
     QSUMM(M,5)=0.
     DO 1130 J=1,NJS
     I=ISOL(J)
1130 QSUMM(M,5)=QSUMM(M,5)+SQSRC1(I)
     QSUMM(M,6)=QLOAD
     QSUMM(M,7)=QACL
     IF(KAUXCL.EQ.0) QSUMM(M,7)=DDH
     QSUMM(M,8)=QISUM
     QSUMM(M,10)=QHSUM

     IF(PRINTM.EQ.0.) GO TO 1200
     PRINT 3017,M,MO,QVHT,QVCL,QAHT,QACL,DD
     PRINT 3006
     DO 1160 IT=1,NT
     I=LT(IT)
1160 PRINT 3007,I,SQSRC1(I),SQSRC2(I),SQCON1(I),SQCON2(I)
C**********************************************
     QSUMM(M,9)=QSUMM(M,6)-QSUMM(M,3)
C**********************************************
C
1200 CONTINUE
C
C -- SUMMARY PRINT OF MONTHLY SUMS
C
     NQS=9
     DO 1210 K=1,NQS
     SUMTOT(K)=QSUMM(NMO,K)
     SUMM1=QSUMM(1,K)
     IF(NMO.EQ.1) GO TO 1210
     DO 1208 M=2,NMO
     SUMM2=QSUMM(M,K)
     QSUMM(M,K)=SUMM2-SUMM1
     SUMM1=SUMM2
     IF(UNITS.EQ.2.AND.K.GT.1) QSUMM(M,K)=QSUMM(M,K)/1000.
1208 CONTINUE
1210  CONTINUE
C
     IF(KAUXCL.EQ.0) PRINT 3029
     PRINT 3019,MTIME,NSTEP,NCALC,KERR,KINC
     DO 1220 M=1,NMO
```

```
      MO=MOY(M)
      IF(QSUMM(M,6).LE.0.) QSUMM(M,6)=1.
      PCTSOL=100.*(1.-QSUMM(M,3)/QSUMM(M,6))
 1220 PRINT 3021,MO,(QSUMM(M,L),L=1,NQS),PCTSOL
      IF(SUMTOT(6).LE.0.) SUMTOT(6)=1.
      PCTSOL=100.*(1.-SUMTOT(3)/SUMTOT(6))
      PRINT 3027,(SUMTOT(K),K=1,NQS),PCTSOL
C
C
      IF(IPRSM.EQ.0) GO TO 1300
C -- PRINT OVERALL SUMS OF NODE AND CONNECTION HEAT FLOWS
      PRINT 3023,QVHT,QVCL,QAHT,QACL,DD,QHSUM
      PRINT 3006
      DO 1230 IT=1,NT
      I=LT(IT)
 1230 PRINT 3007,I,SQSRC1(I),SQSRC2(I),SQCON1(I),SQCON2(I)
      PRINT 3025,(J,I1CON(J),I2CON(J),SQC121(J),SQC122(J),J=1,NCONN)
C
C
 1300 CONTINUE
C
C----FORMATS-----
C
 2999 FORMAT(/30H PASOLE - PASSIVE SOLAR ENERGY)
 3001 FORMAT(/30H $$$$ NO CONVERGENCE AT ITIME=,I3,6H, DAY=,I2,
     1 8H, MONTH=,I2,5X,5HNERR=,I3/5X,8HERRT(I)=/(10E12.4))
 3005 FORMAT(/2X,4HDATE,2X,3HDAY,3X,2HMO,5X,4HQVHT,8X,4HQVCL,8X,4HQAHT,
     1 8X,4HQACL,8X,2HDD/I6,2I5,5E12.4/5X,3HQSP,
     $ 9X,3HDEC,9X,4HDTWD/3E12.4)
 3006 FORMAT(/4X,1HI,5X,6HSQSRC1,6X,6HSQSRC2,6X,6HSQCON1,6X,6HSQCON2)
 3007 FORMAT(I5,4E12.4)
 3017 FORMAT(/13H MONTH INDEX=,I3,5X,14HMONTH OF YEAR=,I3/
     1 5X,4HQVHT,8X,4HQVCL,8X,4HQAHT,8X,4HQACL,8X,2HDD/5E12.4)
 3019 FORMAT(/18H SUMMARY -- MTIME=,I5,3X,6HNSTEP=,I5,3X,6HNCALC=,I5,
     A 3X,5HKERR=,I5,3X,5HKINC=,I5//3X,2HMO,2X,7HDEG DAY,
     1 3X,4HQOUT,3X,5HQHEAT,3X,5HQCOOL,2X,6HQSOLAR,3X,5HQLOAD,4X,
     2 4HQACL,3X,5HQSINC,2X,8HSOL/USED,2X,6HPCTSOL)
 3021 FORMAT(I5,9F8.0,F8.2)
 3023 FORMAT(//7H TOTALS,5X,4HQVHT,8X,4HQVCL,8X,4HQAHT,8X,4HQACL,8X,
     1 2HDD,10X,5HQHSUM/7X,6E12.4)

 3025 FORMAT(/4X,1HJ,3X,2HI1,3X,2HI2,5X,6HSQC121,6X,6HSQC122,
     $ /(3I5,2E12.4))
 3027 FORMAT(/5H SUMS,8F8.0,F8.2)
 3029 FORMAT(/50H NO AUXILIARY COOLING - QACL IS INT(T(IC)-TCMAX)DT)
 4000 FORMAT(/6H TIME=,F5.1,8H   ITER=,I2,8H   I280=,I2,8H   QCIN=,F7.2
     1 /24H NODE TEMPERATURES, T(I)/(10F7.2))
 4001 FORMAT(19H NODE SOURCES, S(I)/(10F7.2))
 4002 FORMAT(35H CONNECTION HEAT FLOW RATE, QC12(J)/(10F7.2))
 4003 FORMAT(/6H DATE=,I7)
      STOP
      END
C
C
C
```

```
      SUBROUTINE SQF(Q,QO,F,DT,SQ1,SQ2)
      QQB=F*Q
      QQA=(1.-F)*QO
      IF(Q*QO.LT.0.) GO TO 10
      DSQA=DT*(QQB+QQA)
      DSQB=0.
      GO TO 20
   10 DSQA=DT*QQA**2/(QQA-QQB)
      DSQB=DT*QQB**2/(QQB-QQA)
   20 SQ1=SQ1+AMAX1(DSQA,DSQB)
      SQ2=SQ2+AMIN1(DSQA,DSQB)
      RETURN
      END
      SUBROUTINE CONTRL
      COMMON/BLAD1/NV,NF,NT,NMAX,KF(50),IC,LV(50),LF(50),LT(50),
     1 KICHNG,KIC,ITMAX,NERR,UNITS,KAUXCL,KCTY,KCALC,KDELT,KCONU
      COMMON/BLAD2/NTIME,MTIME,ITIME,DATE,DAY,DAY1,DAY2,NDAY(12),
     1 MO,MO1,YR,NMO,NDAY1,INDATE,IPRSM,KHEDPR
      COMMON/BLAD3/T(50),TO(50),CPM(50),S(50),SP(50),COND(50,50),
     1 SCON(50),QFACO(50),ERRT(50),FN(50,50,2),FD(50,50,2)
      COMMON/BLAD4/A(50,50),B(50),SQSRC1(50),SQSRC2(50),SQCON1(50),
     1 SQCON2(50),QVHT,QVCL,QAHT,QACL,QHZ,QINC,QTRAN
      COMMON/BLAD5/DELT1,DELT,TIME,SUMKT,QCIN,QCINO,FAC,FRAC,
     1 PI,TIMEX,DEGRAD,TBASE,DD,TMAX,TMIN,TBAR,FACI,REMAIN
      COMMON/BLAD6/QSRC(50),QCON(50),QC12(100),SQC121(100),
     1 SQC122(100),TCMIN,TCMAX,TCMINN,TCMIND,TCMAXN,TCMAXD,DTCOOL
      COMMON/BLAD7/TPRDAY,SBCON,TAMB,QCINT,PRINTH,PRINTD,PRINTM
      COMMON/BLAD8/IDAY,IDPRYR,INDAY,KDATA,QHCONV,ALAT,DLONG,
     1 RINDEX,TOLT,DEC,COSDEC,SINDEC,SINLAT,COSLAT,QSP
     2 ,HRCRIT,QICUT,TMORN,TEVEN,KSHUT,KCOOL,MOSH1,MOSH2
      COMMON/BLAD9/TAD(50),VELD(50),QHD(50),NJS,ISOL(15),
     1 TILT(15),WAZIM(15),AGLZ(15),NGLZ(15),NJA,IAMB(10),
     2 ALFA(15),OHANG(15),OSEPR(15),TGLZ(15),DABS(15)
      COMMON/BLAD10/QDNMAX,RDIFF(15),EX,RHO,TZERO,
     1 NCONN,I1CON(100),I2CON(100),U(100),ACON(100),UD(100),UN(100)
      COMMON/BLAD11/TILTC,AZIMC,RHOC,COSTC,SINTC,FSSC,FSGC,RESNI,
     1 JCP,KND,QDH(24),QFH(24)
      COMMON/TROMBE/VOLF,RCON(50),KVENT,IAIR,JAIR,RLNGTH,RHOSR,
     1 ASPRAT,FCSR,JWA,TRCOAT,IO1,IO2,KWALL,NHOUR,ULOAD,IDAT
C
C
C
      INTEGER DAY,DAY1,DAY2,YR,DATE,UNITS,PRINTH,PRINTD,PRINTM
C----TESTS FOR TEMPERATURE LIMITS ON CONTRL NODE
C----KIC -1 FOR T(IC)<TCMIN WITHOUT QCIN; QCIN>0
C----KIC 0 FOR TCMIN<T(IC)<TCMAX WITHOUT QCIN; QCIN=0
C----KIC 1 FOR T(IC)>TCMAX WITHOUT QCIN; QCIN<0
      IF(KICHNG.EQ.0) REMAIN=1.
      FRAC=REMAIN
      K=KIC+2
      GO TO (100,200,300,800),K
  100 IF(QCIN.GE.0.) GO TO 800
      IF(KVENT.EQ.4.AND.VOLF.GT.0.) GO TO 800
      FRAC=QCINO/(QCINO-QCIN)
      QCIN=0.
```

```
      KIC=0

      KF(IC)=1
      NF=NF-1
      NV=NV+1
      GO TO 500
  200 IF(T(IC).LT.TCMIN) GO TO 220
      IF(T(IC).GT.TCMAX) GO TO 240
      GO TO 800
  220 FRAC=(TCMIN-TO(IC))/(T(IC)-TO(IC))
      T(IC)=TCMIN
      KIC=-1
      GO TO 260
  240 FRAC=(TCMAX-TO(IC))/(T(IC)-TO(IC))
      T(IC)=TCMAX
      KIC=1
  260 KF(IC)=2
      NF=NF+1
      NV=NV-1
      GO TO 500
C
  300 IF(QCIN.LE.0.) GO TO 800
      FRAC=QCINO/(QCINO-QCIN)
      QCIN=0.
      KIC=0
      KF(IC)=1
      NF=NF-1
      NV=NV+1
C
  500 CONTINUE
      IF(FRAC.LE.0.0.OR.FRAC.GT.1.0) FRAC=.01
      FRAC=FRAC*REMAIN
      REMAIN=REMAIN-FRAC
      KICHNG=1
      IF(KDELT.EQ.0) RETURN
      DO 600 IT=1,NT
      I=LT(IT)
      IF(I.EQ.IC) GO TO 600
      T(I)=TO(I)+FRAC*(T(I)-TO(I))
  600 CONTINUE
      CALL PROP
      RETURN
  800 CONTINUE
      KICHNG=0
      RETURN
      END
        SUBROUTINE INDATA
      COMMON/BLAD1/NV,NF,NT,NMAX,KF(50),IC,LV(50),LF(50),LT(50),
     1 KICHNG,KIC,ITMAX,NERR,UNITS,KAUXCL,KCTY,KCALC,KDELT,KCONU
      COMMON/BLAD2/NTIME,MTIME,ITIME,DATE,DAY,DAY1,DAY2,NDAY(12),
     1 MO,MO1,YR,NMO,NDAY1,INDATE,IPRSM,KHEDPR
      COMMON/BLAD3/T(50),TO(50),CPM(50),S(50),SP(50),COND(50,50),
     1 SCON(50),QFACO(50),ERRT(50),FN(50,50,2),FD(50,50,2)
      COMMON/BLAD4/A(50,50),B(50),SQSRC1(50),SQSRC2(50),SQCON1(50),
     1 SQCON2(50),QVHT,QVCL,QAHT,QACL,QHZ,QINC,QTRAN
```

```
      COMMON/BLAD5/DELT1,DELT,TIME,SUMKT,QCIN,QCINO,FAC,FRAC,
     1 PI,TIMEX,DEGRAD,TBASE,DD,TMAX,TMIN,TBAR,FACI,REMAIN
      COMMON/BLAD6/QSRC(50),QCON(50),QC12(100),SQC121(100),
     1 SQC122(100),TCMIN,TCMAX,TCMINN,TCMIND,TCMAXN,TCMAXD,DTCOOL
      COMMON/BLAD7/TPRDAY,SBCON,TAMB,QCINT,PRINTH,PRINTD,PRINTM
      COMMON/BLAD8/IDAY,IDPRYR,INDAY,KDATA,QHCONV,ALAT,DLONG,
     1 RINDEX,TOLT,DEC,COSDEC,SINDEC,SINLAT,COSLAT,QSP
     2 ,HRCRIT,QICUT,TMORN,TEVEN,KSHUT,KCOOL,MOSH1,MOSH2
      COMMON/BLAD9/TAD(50),VELD(50),QHD(50),NJS,ISOL(15),
     1 TILT(15),WAZIM(15),AGLZ(15),NGLZ(15),NJA,IAMB(10),
     2 ALFA(15),OHANG(15),OSEPR(15),TGLZ(15),DABS(15)
      COMMON/BLAD10/QDNMAX,RDIFF(15),EX,RHO,TZERO,
     1 NCONN,I1CON(100),I2CON(100),U(100),ACON(100),UD(100),UN(100)
      COMMON/BLAD11/TILTC,AZIMC,RHOC,COSTC,SINTC,FSSC,FSGC,RESNI,
     1 JCP,KND,QDH(24),QFH(24)
      COMMON/TROMBE/VOLF,RCON(50),KVENT,IAIR,JAIR,RLNGTH,RHOSR,
     1 ASPRAT,FCSR,JWA,TRCOAT,IO1,IO2,KWALL,NHOUR,ULOAD,IDAT

C
      DIMENSION HEDR(20)
      DIMENSION EPSGI(10),EPSGO(10)
C
      INTEGER DAY,DAY1,DAY2,YR,DATE,UNITS,PRINTH,PRINTD,PRINTM
C
C----DEFAULT VALUES OF PROGRAM VARIABLES
C
      DO 3 M=1,12
      IF(M.LE.7) NDAY(M)=30+MOD(M,2)
      IF(M.GT.7) NDAY(M)=31-MOD(M,2)
    3 CONTINUE
      NDAY(2)=28
C -- NMAX IS DIMENSION FOR NODE ARRAYS - NCMAX FOR CONNECTION ARRAYS
      NMAX=50
      NCMAX=100
      KICHNG=0
      IC=2
C INPUT OF VARIABLES FOR RUNNING BOTH WATER AND TROMBE WALL
       READ(5,1805) UNITS,PRINTH,PRINTD,PRINTM,SUNDAT
       READ(5,1806) TILTC,AZIMC,RESNI,RSMWI,ROUTS
C***************************************************************
C**************************************************************
      NMO=12
      PI=3.141592654
      DEGRAD=PI/180.
      QCIN=0.
      QCINO=0.
      INDATE=110168
      DTCOOL=0.
      NDAY1=32
      KCTY=1
      NTIME=24
      ITMAX=1
      IDPRYR=365
      KDATA=0
      RINDEX=1.526
```

```
      EX=0.5*12
      THETAD=60.
      RHO=0.3
      FAC=0.5
      FACI=0.5
      TOLT=1.0
      RHOC=0.3
      KAUXCL=1
      KCALC=1
      KDELT=1
      KCONU=0
      IPRSM=1
      KHEDPR=1
      NHOUR=168
      I01=0
       I02=0
      QICUT=-1.E6
      TMORN=7.
      TEVEN=17.
      MOSH1=0
      MOSH2=0
      RHOSR=0.
      RLNGTH=0.
      FCSR=0.
      ASPRAT=5.0
      DO 100 I=1,NMAX
      KF(I)=0
      CPM(I)=0.
      T(I)=70.
      S(I)=0.
      SP(I)=0.
      QSRC(I)=0.
      QCON(I)=0.

      QFACO(I)=0.
      B(I)=0.
      DO 100 J=1,NMAX
      COND(I,J)=0.
      A(I,J)=0.
  100 CONTINUE
      DO 103 J=1,NCMAX
      UD(J)=0.
      U(J)=0.
      UN(J)=0.
      QC12(J)=0.
      ACON(J)=0.
      I1CON(J)=0
      I2CON(J)=0
  103 CONTINUE
C
C -- VARIABLES FOR MASSIVE EXTERIOR WALLS OPTION
C ***********************************************************
C***********************************************************
C NSGW=NUMBER OF WALL SEGMENTS
C HAIR=OUTSIDE AIR HEAT TRANSFER COEFFIENT
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```
C URMW=ROOM WALL HEAT TRANSFER COEFFIENT
C RWINS=OUTSIDE RESISTANCE ON WALL
C THCW= WALL THERMAL CONDUCTIVITY
C THKW= WALL THICKNESS
C VSPW=WALL VOLUMETRIC THERMAL CAPACITY
C AW=WALL TO SOUTH MASS WALL AREA RATIO
C READING IN OF VARIABLES****************************************
       READ(5,1807) NSGW,HAIR,URMW,RWINS,THCW,THKW,VSPW,AW
C -- USED FOR KCONU OF 1
      UAIR=0.5
      UCIRC=0.
      TREF=70.
C
      GO TO (210,220),UNITS
  210 CONTINUE
C----UNITS 1% BTU,HR,FT,DEG-F
      SBCON=1.7132E-9
      TPRDAY=24.
      TBASE=65.
      QHCONV=1.0
      TZERO=460.
      QDNMAX=317.2
      GO TO 230
  220 CONTINUE
C----UNITS 2% S.I.  UNITS (J,S,M,DEG-C)
      SBCON=5.670E-8
      TPRDAY=86400.
      TBASE=18.
      QHCONV=1.0
      TZERO=273.
      QDNMAX=1000
  230 CONTINUE
      TCMINN=TBASE
      TCMIND=TBASE
      TCMAXN=TBASE
      TCMAXD=TBASE
C
C
C
C -- START SPECIFIC MODEL -- SOUTH MASS WALL
C
C -- TROMBE WALL (KWALL 2) OR WATER WALL (KWALL 1) - PER UNIT AREA OF GLASS
C -- NSGW NON-ZERO FOR MASSIVE EXTERIOR WALLS
C
C -- SET MODEL PARAMETERS
C     NGL-- NUMBER OF PRIMARY SOLAR SOURCE (MASS WALL) GLAZINGS
C     HGHT-- SMW HEIGHT FOR THERMOCIRCULATION CALC.  (FT)
C     ULOAD-- STATIC ROOM HEATING LOAD COEFFICIENT PER UNIT SMW GLAZING
C       AREA (BTU/HR/DEG.F/SQ.FT).   THIS DOES NOT INCLUDE HEAT LOSS THRU

C       SMW OR MASSIVE WALLS.
C     RESNI-- RESISTANCE OF SMW NIGHT INSULATION (DEG.F/(BTU/HR/SQ.FT))
C     KVENT-- THERMOCIRCULATION VENT CONTRL FLAG (SEE PROP)
C     USTRM-- SMW TO ROOM U (BTU/HR/DEG.F/SQ.FT)
C     CAIR-- AIR VOLUMETRIC HEAT CAPACITY (BTU/DEG.F/CU.FT)
```

```
C     GRAV-- ACCELERATION DUE TO GRAVITY (FT/S/S)
C     THCAIR-- AIR THERMAL CONDUCTIVITY (BTU/HR/DEG.F/FT)
C     TILTG-- TILT OF SMW GLAZING OR OF SMW IF BARE (DEG.)
C     AZW-- WALL AZIMUTH (DEG.)
C     ALF-- WALL ABSORBTIVITY
C     TGL-- GLAZING THICKNESS PER LAYER (FT)
C     THCGL-- GLAZING THERMAL CONDUCTIVITY (BTU/HR/SQ.FT/FT)
C     AIRGAP-- SPACING BETWEEN GLAZINGS (FT)
C     EPSW,EPSA,EPSG-- I.R. EMMISSIVITY OF WALL, SKY, AND GLAZING
C     TRCOAT-- TRANSMISSIVITY OF COATING ON INNER SURFACE OF INNER GLAZ
C     FOR HORIZONTAL SPECULAR REFLECTOR, VERTICAL WALL (SEE SUNSRC)
     CONTINUE
C      RLNGTH - REFL. LENGTH/ GLAZ. HEIGHT
C      RHOSR - REFLECTIVITY
C      ASPRAT - LENGTH/WIDTH
C      FCSR - WALL/REFLECTOR VIEW FACTOR
C     CDIS-- VENT DISCHARGE COEFF.
C     AVOAG-- AREA OF ONE ROW (TOP OR BOTTOM) OF VENTS PER UNIT SMW
C      GLAZING AREA
C     ASOAG-- WALL/GLAZING AIR SPACE FLOW AREA PER UNIT SMW GL. AREA
C     CPMR-- SMW HEAT CAPACITANCE (BTU/DEG.F PER UNIT SMW GLAZ. AREA)
C     IAIR-- WALL/GLAZ. AIR SPACE NODE
C     JAIR-- THERMOCIRCULATION CONNECTION (IAIR TO IC)
C     IC-- ROOM AIR NODE (CONTRL NODE)
C     JCP-- CONNECTION OF ULOAD
C     JWA-- CONNECTION BETWEEN SMW SURFACE NODE AND IAIR - STARTS
C      SEQUENCE OF CONNECTIONS THRU GLAZINGS.
C     NSEG-- NUMBER OF SERIES WALL SEGMENTS (SEE MASONRY WALL)
C     THCON-- MASONRY THERMAL CONDUCTIVITY (BTU/HR/DEG.F/FT)
C     THICK-- WALL THICKNESS (FT)
C     VOLSP-- MASONRY VOLUMETRIC HEAT CAPACITY (BTU/DEG.F/CU.FT)
C
C INPUT OF PROGRAM VARIABLES****************************************
      READ(5,1808) NGL,HGHT,ULOAD,KWALL,KVENT
      READ(5,1809) TILTG,AZW,ALF,GRAV
      READ(5,1810) TGL,THCGL,AIRGAP,TRCOAT
      READ(5,1811) AVOAG,ASOAG,CPMR,THCON,VOLSP,NSEG
      READ(5,1812) TCMINN,TCMIND,TCMAXN,TCMAXD,ALAT,IDPRYR,DLONG,KCALC
      READ(5,1813) CDIS,OHANG(1),OSEPR(1)
C INPUT WALL THICKNESS+*****************************************
      READ(5,1814) THICK,TROOM
C**************************************************************
      USTRM=1.5
      CAIR=0.018
      THCAIR=0.015
      IF(NGL.EQ.1) AIRGAP=0
      EPSW=0.9
      EPSG=0.9
      EPSA=0.9
      FCSR=.5*(RLNGTH+1.-SQRT(RLNGTH**2+1.))
      DO 290 IG=1,NGL
      EPSGI(IG)=EPSG
  290 EPSGO(IG)=EPSG
C -- SOME PROGRAM VARIABLES
      INDATE=110168
```

```
      NMO=1
      ITMAX=30
C
C
      KDELT=1
      KCONU=0
       IF(KCALC.EQ.2) KCONU=1
C
C -- INPUT FROM EXTERNAL FILE HERE
C

      READ(5,1996) INDATE,IO1,NDAY1,KWALL,NMO,MOSH1,MOSH2,TMORN,TEVEN
C
C -- CALCULATE THERMAL NETWORK PARAMETERS
      GO TO (294,300),KWALL
  294 CONTINUE
C -- WATER WALL
C -- ASSUMED TO BE SAME AREA AS GLAZING
C -- SINGLE NODE (NODE 1) FOR SMW  -  GLAZINGS START AT NODE 5
C -- NODE 2 IS ROOM AIR -- NODE 3 IS OUTSIDE AMBIENT
C -- NODE 4 IS WALL/GLAZING AIR SPACE
C
      CPM(1)=CPMR
      THCON=0.
      VOLSP=0.
      NCONN=NGL+6
      THICK=0.
      IF(NGL.LE.0)NCONN=3
      JO=NCONN
      NNODE=NGL+4
      IF(NGL.LE.0)NNODE=3
      IO=NNODE
      IAIR=4
      JAIR=4
      IC=2
      JCP=3
      JWA=5
      NSEG=-1
       CON1=0.
       CON2=CON1
      GO TO 310
  300 CONTINUE
C -- MASONRY WALL
C -- ASSUMED TO BE SAME AREA AS GLAZING
C -- NSEG+2 WALL NODES IN SERIES STARTING AT NODE 1.  NODES 1 AND
C      NSEG+2 ARE MASSLESS SURFACE NODES.  NSEG+3 IS ROOM AIR (CONTRL)
C      NSEG+4 IS OUTSIDE AMBIENT, NSEG+5 IS WALL/GLAZ. AIR SPACE.
C      GLAZINGS START AT NSEG+6
C
       THICK=CPMR/VOLSP
       CON1=NSEG*(THCON/THICK)
      CON2=2.*CON1
      CPMRI=CPMR/NSEG
C
      NCONN=NSEG+NGL+7
```

```
      IF(NGL.LE.0) NCONN=NSEG+4
      J0=NCONN
      NNODE=NSEG+NGL+5
      IF(NGL.LE.0) NNODE=NSEG+4
      I0=NNODE
      IAIR=NSEG+5
      JAIR=NSEG+5
      IC=NSEG+3
      JCP=NSEG+4
  310 CONTINUE
C -- FOR BOTH TYPES OF WALL
      JWA=NSEG+6
      NJA=1
      IAMB(1)=JCP
      NJS=1
      ISOL(1)=1
C
C -- CONNECTION PARAMETERS
      I1CON(1)=1
      I2CON(1)=IAIR+1
      ACON(1)=1.0
      IF(NGL.LE.0) I2CON(1)=IAMB(1)
      J2=NSEG+2
      DO 320 J=2,JCP
      I1CON(J)=J-1
      I2CON(J)=J

      ACON(J)=1.0
      CONI=CON1
      IF(J.EQ.2.OR.J.EQ.J2)CONI=CON2
      UN(J)=CONI
      UD(J)=CONI
  320 CONTINUE
      UN(JCP-1)=USTRM
      UD(JCP-1)=USTRM
      UN(JCP)=ULOAD
      UD(JCP)=ULOAD
      IF(NGL.LE.0) GO TO 335
      I1CON(JAIR)=IAIR
      I2CON(JAIR)=IC
      ACON(JAIR)=1.0
      I1CON(JAIR+1)=1
      I2CON(JAIR+1)=IAIR
      ACON(JAIR+1)=1.0
      I1CON(JAIR+2)=IAIR
      I2CON(JAIR+2)=IAIR+1
      ACON(JAIR+2)=1.0
      J1=NSEG+8
      J2=J1+NGL-1
      DO 330 J=J1,J2
      I1CON(J)=J-2
      I2CON(J)=J-1
      ACON(J)=1.0
  330 CONTINUE
      I2CON(J2)=IAMB(1)
```

```
 335 CONTINUE
C
C -- NODE PARAMETERS
     DO 340 I=1,NNODE
     T(I)=TREF
     KF(I)=1
 340 CONTINUE
     I=IAMB(1)
     KF(I)=2
     IF(KWALL.EQ.1)GO TO 352
     I2=NSEG+1
     DO 350 I=2,I2
 350 CPM(I)=CPMRI
 352 CONTINUE
C
C
C -- CALCULATE CONSTANTS FOR TEMPERATURE-DEPENDENT U'S IN PROP
     RCON(1)=CDIS*AVOAG*SQRT(GRAV*HGHT)*3600.
     RCON(2)=2.*CAIR
     RCON(3)=1./(3600.*ASOAG)
     RCON(4)=THCAIR/(AIRGAP+.0001)
     RCON(5)=ROUTS
     RCON(6)=TGL/THCGL/2
C -- CONSTANTS FOR RADIATION U'S
     RCON(10)=SBCON/(1./EPSW+1./EPSA-1.)
     IF(NGL.LE.0)GO TO 370
     RCON(10)=SBCON/(1./EPSW+1./EPSGI(1)-1.)
     IF(NGL.EQ.1) GO TO 365
     NG=NGL-1
     DO 360 IG=1,NG
 360 RCON(IG+10)=SBCON/(1./EPSGO(IG)+1./EPSGI(IG+1)-1.)
 365 RCON(NGL+10)=SBCON/(1./EPSGO(NGL)+1./EPSA-1.)
 370 CONTINUE
C
C
C -- SOLAR SOURCE INFORMATION
     TILT(1)=TILTG
     WAZIM(1)=AZW
     ALFA(1)=ALF
     AGLZ(1)=1.0
     NGLZ(1)=NGL
     TGLZ(1)=TGL

     AINC=THETAD*DEGRAD
     CALL GLOSS(NGL,AINC,RINDEX,EX,TGL,TRREF,TRABS)
     RDIFF(1)=1.-TRREF
     DABS(1)=1.-TRABS
C
     IF(NSGW.LE.0) GO TO 700
C -- OPTIONAL EXTRA FOR MASSIVE EXTERIOR WALLS
C      NSGW-- NUMBER OF WALL SEGMENTS
C      HAIR-- OUTSIDE AIR FILM COEFF.
C      URMW-- ROOM TO WALL U (INCLUDES ANY INTERIOR INSULATION)
C      RWINS-- RESISTANCE OF ANY EXTERIOR WALL INSULATION
C    THCW---THERMAL CONDUCTIVITY OF WALL MATERIAL
```

```
C     THKW-- WALL THICKNESS
C     VSPW-- WALL MAT. VOLUMETRIC HEAT CAPACITY
C     AW-- WALL AREA/ SMW GLAZING AREA
C
      IF(TROOM.GE.200.0) GO TO 421
      NCONN=JO+NSGW+3
C*********************************************
C NUMBER OF NODES IS INCREASED.
C
      NNODE=IO+NSGW+3
       HAIR=URMW
      UWOUT=1./(RWINS+1./HAIR)
      CPMW=AW*THKW*VSPW
      CPMWI=CPMW/NSGW
      CC1=NSGW*THCW/THKW
      CC2=2.*CC1
C
      J=JO+1
      I1CON(J)=IC
      I2CON(J)=IO+1
      ACON(J)=AW
      UD(J)=URMW
      UN(J)=URMW
      JJ2=NSGW+1
      DO 410 JJ=1,JJ2
      J=JO+JJ+1
      I=IO+JJ
      I1CON(J)=I
      I2CON(J)=I+1
      ACON(J)=AW
      CCI=CC1
      IF(JJ.EQ.1.OR.JJ.EQ.JJ2) CCI=CC2
      UD(J)=CCI
      UN(J)=CCI
  410 CONTINUE
      J=JO+NSGW+3
      I=IO+NSGW+2
      I1CON(J)=I
C****************************************************
C AN EXTRA ROOM NODE AT A SET ROOM TEMP TROOM IS ADDED.
C
      I2CON(J)=I+1
       IT=I+1
       T(IT)=TROOM
       KF(IT)=2
      ACON(J)=AW
      UN(J)=UWOUT
      UD(J)=UWOUT
C -- ADJUST STATIC LOAD CONNECTION
      UWO=1./(1./URMW+THKW/THCW+1./UWOUT)
      USTAT=ULOAD-UWO*AW
       IF(USTAT.LT.0.)USTAT=0
      UD(JCP)=USTAT
      UN(JCP)=USTAT
C
```

```
C LOSS TO OUTSIDE SET AT ULOAD FOR ALL COMPONENTS
C WITH OUTSIDE TEMP
      UN(JCP)=ULOAD

      UD(JCP)=ULOAD
C
C*********************************************
C
      I1=I0+1
      I2=I0+NSGW+2
      DO 420 I=I1,I2
      T(I)=70.
      KF(I)=1
      IF(I.EQ.I1.OR.I.EQ.I2) GO TO 420
      CPM(I)=CPMWI
  420 CONTINUE
C -- END EXTERIOR WALL CALC.
C    EXTRA MASSIVE WALL TO THE OUTSIDE
C
C*********************************************
  421 NCONN=J0+NSGW+3
      NNODE=I0+NSGW+2
      UWOUT=1./(RWINS+1./HAIR)
      CPMW=AW*THKW*VSPW
       CPMWI=CPMW/NSGW
      CC1=NSGW*THCW/THKW
      CC2=2.*CC1
C
      J=J0+1
      I1CON(J)=IC
      I2CON(J)=I0+1
      ACON(J)=AW
      UD(J)=URMW
      UN(J)=URMW
      JJ2=NSGW+1
      DO 422 JJ=1,JJ2
      J=J0+JJ+1
      I=I0+JJ
      I1CON(J)=I
      I2CON(J)=I+1
      ACON(J)=AW
      CCI=CC1
      IF(JJ.EQ.1.OR.JJ.EQ.JJ2) CCI=CC2
      UD(J)=CCI
      UN(J)=CCI
  422 CONTINUE
      J=J0+NSGW+3
      I=I0+NSGW+2
      I1CON(J)=I
      I2CON(J)=IAMB(1)
      ACON(J)=AW
      UN(J)=UWOUT
      UD(J)=UWOUT
C -- ADJUST STATIC LOAD CONNECTION
      UWO=1./(1./URMW+THKW/THCW+1./UWOUT)
```

```
      USTAT=ULOAD-UWO*AW
      IF(USTAT.LT.0.)USTAT=0
      UD(JCP)=USTAT
      UN(JCP)=USTAT
C
      I1=I0+1
      I2=I0+NSGW+2
      DO 423 I=I1,I2
      T(I)=70.
      KF(I)=1
      IF(I.EQ.I1.OR.I.EQ.I2) GO TO 423
      CPM(I)=CPMWI
  423 CONTINUE
C -- END EXTERIOR WALL CALC.
  700 CONTINUE
C
      IF(KCONU.NE.1) GO TO 800
C -- FOR CONSTANT COEFFICIENTS UN, UD
      TFUNC=RADFN(TREF,TREF,TZERO)

      IF(NGL.GT.0) GO TO 720
      UD(1)=HAIR
      UN(1)=1./(1./HAIR+RESNI)
      GO TO 800
  720 CONTINUE
      UN(JAIR)=UCIRC
      UD(JAIR)=UCIRC
      UN(JWA)=UAIR
      UD(JWA)=UAIR
      UD(JWA+1)=1./(1./UAIR+RCON(6))
      UN(JWA+1)=1./(1./UD(JWA+1)+RESNI/2.)
      URSP=RCON(10)*TFUNC
      UD(1)=1./(1./URSP+RCON(6))
      UN(1)=1./(1./UD(1)+RESNI/2.)
      J1=JWA+2
      J2=JWA+NGL
      KX=10
      IF(NGL.EQ.1) GO TO 760
      DO 740 J=J1,J2
      KX=KX+1
      I1=I1CON(J)
      I2=I2CON(J)
      UGAP=AMAX1(RCON(4),0.36)+RCON(KX)*TFUNC
      UD(J)=1./(1./UGAP+2.*RCON(6))
      UN(J)=UD(J)
      IF(J.EQ.J1) UN(J)=1./(1./UD(J)+RESNI/2.)
  740 CONTINUE
  760 KX=10+NGL
      J=J2+1
      I1=I1CON(J)
      I2=I2CON(J)
      UD(J)=1./(1./HAIR+RCON(6))
      UN(J)=UD(J)
      IF(NGL.EQ.1) UN(J)=1./(1./UD(J)+RESNI/2.)
  800 CONTINUE
```

```
C
C -- OPAQUE INSULATION ON OUTSIDE OF SOUTH MASS WALL (RSMWI)
      IF(RSMWI.LE.0.01) GO TO 820
      NCONN=NCONN+1
      NNODE=NNODE+1
      I1CON(JWA)=NNODE
      I1CON(1)=NNODE
      J=NCONN
      I1CON(J)=1
      I2CON(J)=NNODE
      ACON(J)=1.0
      UN(J)=1./RSMWI
      UD(J)=1./RSMWI
      KF(NNODE)=1
      T(NNODE)=70
      ISOL(1)=NNODE
  820 CONTINUE
C
C
C -- END PROBLEM DATA
C
C -- PRINT DATA
      IF(KWALL.EQ.1.OR.KWALL.EQ.0) PRINT 1998,INDATE,ULOAD
      IF(KWALL.EQ.2) PRINT 1999,INDATE,ULOAD
      IF(KHEDPR.EQ.0) GO TO 1000
      PRINT 2001,(J,I1CON(J),I2CON(J),UD(J),UN(J),ACON(J),J=1,NCONN)
      PRINT 2003,(IAMB(J),J=1,NJA)
      PRINT 2007,(J,ISOL(J),NGLZ(J),TILT(J),WAZIM(J),ALFA(J),
     1 AGLZ(J),OHANG(J),OSEPR(J),TGLZ(J),DABS(J),J=1,NJS)
      PRINT 2009,NMAX,IC,NTIME,NSEG,NMO,NDAY1,ITMAX,UNITS,KDATA,
     1 KWALL,KCALC,KDELT,KCONU,KCTY,NSGW,KAUXCL,KVENT,
     2 JCP,JWA,IAIR,JAIR
      PRINT 2011,QHCONV,ALAT,DLONG,RINDEX,TMORN,TEVEN,TZERO,QDNMAX,
     1 RHO,EX,FAC,TOLT,TCMINN,TCMIND,TILTC,AZIMC,RHOC,FACI,TCMAXD,
     2 THCON,THICK,VOLSP,ULOAD,RESNI,RLNGTH,RHOSR,ASPRAT,FCSR,CPMR,

     3 RSMWI
      IF(NSGW.LE.0) GO TO 1000
      PRINT 2013,RWINS,UWOUT,THCW,THKW,VSPW,AW
 1000 CONTINUE
C
 1805 FORMAT(5I6)
 1806 FORMAT(5F6.2)
 1807 FORMAT(I2,3F4.1,F5.1,F8.3,F5.2,F6.2)
 1808 FORMAT(I2,F4.1,F6.2,2I5)
 1809 FORMAT(F5.1,F5.1,F5.2,F4.1)
 1810 FORMAT(F7.4,F5.2,F7.4,F5.2)
 1811 FORMAT(F8.4,F8.4,3F5.1,I4)
 1812 FORMAT(4F4.0,F5.2,I4,F5.2,I4)
 1813 FORMAT(F5.2,2F6.2)
 1814 FORMAT(F7.3,F4.0)
 1996 FORMAT(I6,I7,5I3,2F5.1)
 1998 FORMAT(/42H WATER WALL - PER UNIT WALL AREA - INDATE=,I6,
     1 5X,6HULOAD=,F6.3)
 1999 FORMAT(/43H TROMBE WALL - PER UNIT WALL AREA - INDATE=,I6,
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     1 5X,6HULOAD=,F6.3)
2001 FORMAT(/24H CONDUCTANCE CONNECTIONS/4X,1HJ,3X,2HI1,
     $ 3X,2HI2,5X,2HUD,10X,2HUN,10X,4HACON/(3I5,3E12.4))
2003 FORMAT(/26H AMBIENT TEMPERATURE NODES/4X,2HI=,14I5)
2007 FORMAT(19H SOLAR HEAT SOURCES,/4X,7HJ   ISOL,5H NGLZ,2X,
     1 4HTILT,2X,5HWAZIM,3X,4HALFA,3X,4HAGLZ,2X,5HOHANG,2X,
     2 5HOSEPR,3X,4HTGLZ,3X,4HDABS/3I5,2F7.2,F7.4,F7.2,4F7.4)
2009 FORMAT(/5X,4HNMAX,5X,2HIC,4X,5HNTIME,4X,4HNSEG,4X,3HNMO,
     $  4X,5HNDAY1,3X,5HITMAX,3X,5HUNITS,3X,5HKDATA,
     $ /9I8/4X,5HKWALL,3X,5HKCALC,3X,5HKDELT,3X,5HKCONU,
     $ 3X,4HKCTY,4X,4HNSGW,4X,6HKAUXCL,3X,5HKVENT/
     $ 8I8/6X,3HJCP,5X,3HJWA,4X,4HIAIR,4X,4HJAIR/4I8)
2011 FORMAT(/5X,6HQHCONV,6X,4HALAT,8X,5HDLONG,7X,6HRINDEX,6X,
     1 5HTMORN,7X,5HTEVEN/6E12.4/5X,5HTZERO,7X,6HQDNMAX,6X,3HRHO,
     2 9X,2HEX,10X,3HFAC,9X,4HTOLT/6E12.4/5X,6HTCMINN,6X,
     3 6HTCMIND,6X,5HTILTC,7X,5HAZIMC,7X,4HRHOC,8X,4HFACI/6E12.4/
     4 5X,6HTCMAXD,6X,5HTHCON,7X,5HTHICK,7X,5HVOLSP,7X,
     5 5HULOAD,7X,5HRESNI/6E12.5/5X,6HRLNGTH,6X,5HRHOSR,
     6 7X,6HASPRAT,6X,4HFCSR,8X,4HCPMR,8X,5HRSMWI/6E12.4)
2013 FORMAT(/5X,5HRWINS,7X,5HUWOUT,7X,4HTHCW,8X,4HTHKW,
     $ 8X,4HVSPW,8X,2HAW,/6E12.4)
CC
      RETURN
      END
         SUBROUTINE PRIME
      COMMON/BLAD1/NV,NF,NT,NMAX,KF(50),IC,LV(50),LF(50),LT(50),
     1 KICHNG,KIC,ITMAX,NERR,UNITS,KAUXCL,KCTY,KCALC,KDELT,KCONU
      COMMON/BLAD2/NTIME,MTIME,ITIME,DATE,DAY,DAY1,DAY2,NDAY(12),
     1 MO,MO1,YR,NMO,NDAY1,INDATE,IPRSM,KHEDPR
      COMMON/BLAD3/T(50),TO(50),CPM(50),S(50),SP(50),COND(50,50),
     1 SCON(50),QFACO(50),ERRT(50),FN(50,50,2),FD(50,50,2)
      COMMON/BLAD4/A(50,50),B(50),SQSRC1(50),SQSRC2(50),SQCON1(50),
     1 SQCON2(50),QVHT,QVCL,QAHT,QACL,QHZ,QINC,QTRAN
      COMMON/BLAD5/DELT1,DELT,TIME,SUMKT,QCIN,QCINO,FAC,FRAC,
     1 PI,TIMEX,DEGRAD,TBASE,DD,TMAX,TMIN,TBAR,FACI,REMAIN
      COMMON/BLAD6/QSRC(50),QCON(50),QC12(100),SQC121(100),
     1 SQC122(100),TCMIN,TCMAX,TCMINN,TCMIND,TCMAXN,TCMAXD,DTCOOL
      COMMON/BLAD7/TPRDAY,SBCON,TAMB,QCINT,PRINTH,PRINTD,PRINTM
      COMMON/BLAD8/IDAY,IDPRYR,INDAY,KDATA,QHCONV,ALAT,DLONG,
     1 RINDEX,TOLT,DEC,COSDEC,SINDEC,SINLAT,COSLAT,QSP
     2 ,HRCRIT,QICUT,TMORN,TEVEN,KSHUT,KCOOL,MOSH1,MOSH2
      COMMON/BLAD9/TAD(50),VELD(50),QHD(50),NJS,ISOL(15),
     1 TILT(15),WAZIM(15),AGLZ(15),NGLZ(15),NJA,IAMB(10),
     2 ALFA(15),OHANG(15),OSEPR(15),TGLZ(15),DABS(15)
      COMMON/BLAD10/QDNMAX,RDIFF(15),EX,RHO,TZERO,
     1 NCONN,I1CON(100),I2CON(100),U(100),ACON(100),UD(100),UN(100)
      COMMON/BLAD11/TILTC,AZIMC,RHOC,COSTC,SINTC,FSSC,FSGC,RESNI,
     1 JCP,KND,QDH(24),QFH(24)
      COMMON/TROMBE/VOLF,RCON(50),KVENT,IAIR,JAIR,RLNGTH,RHOSR,
     1 ASPRAT,FCSR,JWA,TRCOAT,IO1,IO2,KWALL,NHOUR,ULOAD,IDAT
      DIMENSION NVO(2)

C
C
C
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```
      INTEGER DAY,DAY1,DAY2,YR,DATE,UNITS,PRINTH,PRINTD,PRINTM
C
      TCMIN=TCMINN
      TCMAX=TCMAXN
      MO1=INDATE/10000
      INDAY=INDATE/100-MO1*100
      IF(IDPRYR.EQ.366) NDAY(2)=29
      DELT1=TPRDAY/FLOAT(NTIME)
      IF(FAC.EQ.0) ITMAX=1
C
      DO 100 J=1,NCONN
      I1=I1CON(J)
      I2=I2CON(J)
      COND(I1,I2)=UN(J)*ACON(J)
      COND(I2,I1)=UN(J)*ACON(J)
  100 CONTINUE
      DO 200 I=1,NMAX
      SCON(I)=0.
      DO 200 J=1,NMAX
  200 SCON(I)=SCON(I)+COND(I,J)
C
      IDAY=INDAY-1
      IF(MO1.LE.1) GO TO 500
      M2=MO1-1
      DO 480 M=1,M2
  480 IDAY=IDAY+NDAY(M)
  500 CONTINUE
C
      SINLAT=SIN(DEGRAD*ALAT)
      COSLAT=COS(DEGRAD*ALAT)
C
      COSTC=COS(TILTC*DEGRAD)
      SINTC=SIN(DEGRAD*TILTC)
      FSSC=.5*(1.+COSTC)
      FSGC=.5*(1.-COSTC)
C -- IF TEMP LIMITS ARE WITHIN 0.1 DEG., T(IC) IS FIXED AT TCMIN
C --  FOR ALL TIME AND KIC IS SET TO 2 AS A FLAG
      KIC=0
      BANDD=ABS(TCMAXD-TCMIND)
      BANDN=ABS(TCMAXN-TCMINN)
      IF(BANDD.GT.0.1.OR.BANDN.GT.0.1) GO TO 605
      KIC=2
      KF(IC)=2
      T(IC)=TCMINN
  605 CONTINUE
C
C----COLLCT AND IDENTIFY NODES
      NV=0
      NF=0
      NT=0
      DO 607 I=1,NMAX
      LV(I)=0
      LF(I)=0
  607 LT(I)=0
      DO 640 I=1,NMAX
```

```
      K=KF(I)
      IF(K.NE.1.AND.K.NE.2) GO TO 640
      IF(I.EQ.IC) GO TO 640
      GO TO (610,620),K
C----VARIABLE TEMP NODES
  610 NV=NV+1
      LV(NV)=I
      GO TO 630
C----FIXED TEMP NODES
  620 NF=NF+1
      LF(NF)=I
  630 NT=NT+1

      LT(NT)=I
  640 CONTINUE
C----CONTRL NODE PUT AT END
      LF(NF+1)=IC
      LV(NV+1)=IC
      LT(NT+1)=IC
      NT=NT+1
      IF(KF(IC).EQ.1) NV=NV+1
      IF(KF(IC).EQ.2) NF=NF+1
C
C -- KCALC IS 2 FOR SIMPLE CALCULATION IN WHICH ALL COND(I,J), CPM(I),
C --  SP(I), AND DELT ARE CONSTANT FOR ALL TIME RESULTING IN CONSTANT
C --  A(I,J) ARRAYS FOR NIGHT AND DAY FOR CONTRL TEMP FIXED AND
C --  CONTRL TEMP VARIABLE (FOUR SETS OF COEFFICIENTS) --
C -- CALCULATE CONSTANT COEFFICIENTS F(I,J) (FN(I,J,K) OR FD(I,J,K))
C --  IN - T(I)=SUMâF(I,J)*B(J)ê; I=1,NV
C -- KDELT IS ZERO FOR NO PARTITIONING OF TIME INCREMENT WHEN OPERATING
C --  MODE OF CONTRL NODE CHANGES - KDELT MUST BE ZERO FOR KCALC OF 2.
C -- KCONU IS ONE FOR UN AND UD CONSTANT FOR ALL CONNECTIONS
C --  KCONU MUST BE 1 FOR KCALC OF 2
C
      IF(KCALC.NE.2) GO TO 1000
      KDELT=0
      KCONU=1
      DO 900 KND=1,2
      DO 700 J=1,NCONN
      I1=I1CON(J)
      I2=I2CON(J)
      GO TO (650,655),KND
  650 U(J)=UN(J)
      GO TO 660
  655 U(J)=UD(J)
  660 COND(I1,I2)=U(J)*ACON(J)
      COND(I2,I1)=U(J)*ACON(J)
  700 CONTINUE
      DO 720 IT=1,NT
      I1=LT(IT)
      SCON(I1)=0
      DO 720 JT=1,NT
      I2=LT(JT)
      SCON(I1)=SCON(I1)+COND(I1,I2)
  720 CONTINUE
```

```
      IF(KF(IC).EQ.1) NVO(1)=NV
      IF(KF(IC).EQ.2) NVO(1)=NV+1
      NVO(2)=NVO(1)-1
      DO 900 IX=1,2
      NVOX=NVO(IX)
      DO 800 K=1,NVOX
      DO 750 IV=1,NVOX
      B(IV)=0.
      I=LV(IV)
      FAK=FAC
      IF(CPM(I).LE.0.) FAK=1
      DO 750 JV=1,NVOX
      J=LV(JV)
      A(IV,JV)=-FAK*COND(I,J)
      IF(I.EQ.J) A(IV,JV)=CPM(I)/DELT1+FAK*(SCON(I)-SP(I))
  750 CONTINUE
      B(K)=1.
        CALL MCFLSS(NMAX,NVOX,A,B)
      DO 800 J=1,NVOX
      GO TO(772,774),KND
  772 FN(J,K,IX)=B(J)
      GO TO 800
  774 FD(J,K,IX)=B(J)
  800 CONTINUE
C
      IF(KHEDPR.EQ.0) GO TO 900
      PRINT 3711,KND,IX,NVOX
      DO 3701 I=1,NVOX

      GO TO(3691,3692),KND
 3691 PRINT 3703,(FN(I,J,IX),J=1,NVOX)
      GO TO 3701
 3692 PRINT 3703,(FD(I,J,IX),J=1,NVOX)
 3701 CONTINUE
 3703 FORMAT(10E12.4)
 3711 FORMAT(5H KND=,I5,5X,3HIX=,I5,5X,5HNVOX=,
     $ I5//19H  I    F(I,J),J=1,NV)
C
  900 CONTINUE
 1000 CONTINUE
      RETURN
      END
          SUBROUTINE PROP
      COMMON/BLAD1/NV,NF,NT,NMAX,KF(50),IC,LV(50),LF(50),LT(50),
     1 KICHNG,KIC,ITMAX,NERR,UNITS,KAUXCL,KCTY,KCALC,KDELT,KCONU
      COMMON/BLAD2/NTIME,MTIME,ITIME,DATE,DAY,DAY1,DAY2,NDAY(12),
     1 MO,MO1,YR,NMO,NDAY1,INDATE,IPRSM,KHEDPR
      COMMON/BLAD3/T(50),TO(50),CPM(50),S(50),SP(50),COND(50,50),
     1 SCON(50),QFACO(50),ERRT(50),FN(50,50,2),FD(50,50,2)
      COMMON/BLAD4/A(50,50),B(50),SQSRC1(50),SQSRC2(50),SQCON1(50),
     1 SQCON2(50),QVHT,QVCL,QAHT,QACL,QHZ,QINC,QTRAN
      COMMON/BLAD5/DELT1,DELT,TIME,SUMKT,QCIN,QCINO,FAC,FRAC,
     1 PI,TIMEX,DEGRAD,TBASE,DD,TMAX,TMIN,TBAR,FACI,REMAIN
      COMMON/BLAD6/QSRC(50),QCON(50),QC12(100),SQC121(100),
     1 SQC122(100),TCMIN,TCMAX,TCMINN,TCMIND,TCMAXN,TCMAXD,DTCOOL
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      COMMON/BLAD7/TPRDAY,SBCON,TAMB,QCINT,PRINTH,PRINTD,PRINTM
      COMMON/BLAD8/IDAY,IDPRYR,INDAY,KDATA,QHCONV,ALAT,DLONG,
     1 RINDEX,TOLT,DEC,COSDEC,SINDEC,SINLAT,COSLAT,QSP
     2 ,HRCRIT,QICUT,TMORN,TEVEN,KSHUT,KCOOL,MOSH1,MOSH2
      COMMON/BLAD9/TAD(50),VELD(50),QHD(50),NJS,ISOL(15),
     1 TILT(15),WAZIM(15),AGLZ(15),NGLZ(15),NJA,IAMB(10),
     2 ALFA(15),OHANG(15),OSEPR(15),TGLZ(15),DABS(15)
      COMMON/BLAD10/QDNMAX,RDIFF(15),EX,RHO,TZERO,
     1 NCONN,I1CON(100),I2CON(100),U(100),ACON(100),UD(100),UN(100)
      COMMON/BLAD11/TILTC,AZIMC,RHOC,COSTC,SINTC,FSSC,FSGC,RESNI,
     1 JCP,KND,QDH(24),QFH(24)
      COMMON/TROMBE/VOLF,RCON(50),KVENT,IAIR,JAIR,RLNGTH,RHOSR,
     1 ASPRAT,FCSR,JWA,TRCOAT,IO1,IO2,KWALL,NHOUR,ULOAD,IDAT
      DIMENSION FLUX(50)
C
      INTEGER DAY,DAY1,DAY2,YR,DATE,UNITS,PRINTH,PRINTD,PRINTM
C
C -- KVENT IS 0 FOR NO VENTS OR VENTS ALWAYS CLOSED
C -- KVENT IS 1 FOR VENTS ALWAYS OPEN
C -- KVENT IS 2 FOR NO REVERSE VENT FLOW (RVF)
C -- KVENT IS 4 FOR THERMOSTATICALLY CONTRLLED VENT (NO RVF)
C
C -- VOLF IS VOLUMETRIC FLOW RATE/GLASS AREA
      IF(KCONU.EQ.1) GO TO 75
C -- HAIR IS OUTSIDE AIR FILM COEFFICIENT
      HAIR=2.0+4.0*VELD(ITIME)/15.
C -- ADD TRANSPARANT OUTSIDE RESISTANCE (RCON(5)) FOR NGL=0
      IF(NGLZ(1).EQ.0)HAIR=1./(1./HAIR+RCON(5))
C
      VOLF=0.
      IF(KVENT.EQ.0) GO TO 40
      DTOT=(T(IAIR)-T(IC))/(T(IAIR)+TZERO)
      VOLFX=RCON(1)*SQRT(ABS(DTOT))
      IF(DTOT.LT.0.) VOLFX=-VOLFX
      GO TO(10,20,10,28),KVENT
   10 VOLF=VOLFX
      GO TO 40
   20 IF(VOLFX.GT.0.) VOLF=VOLFX
      GO TO 40
   28 CONTINUE
      IF(MTIME.EQ.1.OR.KIC.NE.-1.OR.VOLFX.LE.0.) GO TO 40
      XTRA=0.
      DO 30 IT=1,NT
      I=LT(IT)

      IF(I.EQ.IAIR) GO TO 30
      XTRA=XTRA+COND(IC,I)*(T(IC)-T(I))
   30 CONTINUE
      XTRA=XTRA-S(IC)-SP(IC)*T(IC)
      VOLF=XTRA/ACON(JAIR)/(T(IAIR)-T(IC))/RCON(2)
      IF(VOLF.LT.0.) VOLF=0.
      IF(VOLF.GT.VOLFX) VOLF=VOLFX
   40 CONTINUE
C
C -- CALCULATE SPECIFIC CONDUCTANCES (UN,UD) FOR TEMPERATURE AND
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```
C --  TIME DEPENDENT CONNECTIONS
      NGL=NGLZ(1)
      IF(NGL.GT.0) GO TO 45
C -- NO COLLCTOR GLAZINGS
      UN(1)=HAIR
      UD(1)=HAIR
      IF(KSHUT.NE.1) GO TO 43
      UN(1)=1./(1./HAIR+RESNI)
      UD(1)=UN(1)
   43 CONTINUE
C
          GO TO 75
C
C -- NGL COLLCTOR GLAZINGS WITH RADIATION/CONVECTION CONNECTIONS
   45 CONTINUE
      VFLOW=ABS(VOLF)
      UN(JAIR)=RCON(2)*VFLOW
      UD(JAIR)=RCON(2)*VFLOW
      UAIR=1.+.21*RCON(3)*VFLOW
      DO 47 J=1,NCONN
      I1=I1CON(J)
      I2=I2CON(J)
   47 FLUX(J)=U(J)*(T(I1)-T(I2))
      UN(JWA)=UAIR
      UD(JWA)=UAIR
      I2=I2CON(1)
      J=JWA+1
      RG2=RCON(6)
      IF(KSHUT.EQ.1) RG2=RG2+RESNI/2
      T2=T(I2)+(FLUX(1)+FLUX(J))*RG2
      T1=T(1)
      UN(J)=1./(1./UAIR+RG2)
      UD(J)=1./(1./UAIR+RG2)
      URSP=RCON(10)*RADFN(T1,T2,TZERO)
      UN(1)=1./(1./URSP+RG2)
      UD(1)=1./(1./URSP+RG2)
      J1=JWA+2
      J2=JWA+NGL
      KX=10
      IF(NGL.EQ.1) GO TO 60
      DO 50 J=J1,J2
      KX=KX+1
      I1=I1CON(J)
      I2=I2CON(J)
      RG1=RCON(6)
      RG2=RG1
      IF(KSHUT.EQ.1.AND.J.EQ.J1)RG1=RG1+RESNI/2
      T1=T(I1)-FLUX(J)*RG1
      T2=T(I2)+FLUX(J)*RG2
      DELTS=ABS(T1-T2)
      TBARS=.5*(T1+T2)+TZERO
C -- HCRIT IS THE MINIMUM ATTAINABLE CONVECTION COEFF.  IN VERTICAL
C --  AIR SPACE
      HCRIT=1.032*(DELTS/TBARS)**0.333
      HCONV=RCON(4)
```

```
      IF(HCONV.LT.HCRIT)HCONV=HCRIT
      UGAP=RCON(KX)*RADFN(T1,T2,TZERO)+HCONV
      UN(J)=1./(1./UGAP+RG1+RG2)
      UD(J)=1./(1./UGAP+RG1+RG2)
   50 CONTINUE

   60 KX=10+NGL
      J=J2+1
      I1=I1CON(J)
      I2=I2CON(J)
      RG1=RCON(6)
      IF(KSHUT.EQ.1.AND.NGL.EQ.1) RG1=RG1+RESNI/2
      UN(J)=1./(1./HAIR+RG1)
      UD(J)=1./(1./HAIR+RG1)
   75 CONTINUE
C
C -- CALCULATE U(J),COND(I1,I2),SCON(I)
C -- THIS PART SHOULD BE KEPT FOR ANY MODELS
      I=IAMB(1)
      T(I)=TAMB
      DO 100 J=1,NCONN
      I1=I1CON(J)
      I2=I2CON(J)
      GO TO (91,93),KND
   91 U(J)=UN(J)
      GO TO 95
   93 U(J)=UD(J)
   95 COND(I1,I2)=U(J)*ACON(J)
      COND(I2,I1)=U(J)*ACON(J)
  100 CONTINUE
C
      DO 800 IT=1,NT
      I1=LT(IT)
      SCON(I1)=0
      DO 800 JT=1,NT
          I2=LT(JT)
      SCON(I1)=SCON(I1)+COND(I1,I2)
  800 CONTINUE
      RETURN
      END
            FUNCTION RADFN(T1,T2,T0)
      TT1=T1+T0
      TT2=T2+T0
      RADFN=(TT1**2+TT2**2)*(TT1+TT2)
      RETURN
      END
           SUBROUTINE DAYLY
      COMMON/BLAD1/NV,NF,NT,NMAX,KF(50),IC,LV(50),LF(50),LT(50),
     1 KICHNG,KIC,ITMAX,NERR,UNITS,KAUXCL,KCTY,KCALC,KDELT,KCONU
      COMMON/BLAD2/NTIME,MTIME,ITIME,DATE,DAY,DAY1,DAY2,NDAY(12),
     1 MO,MO1,YR,NMO,NDAY1,INDATE,IPRSM,KHEDPR
      COMMON/BLAD3/T(50),TO(50),CPM(50),S(50),SP(50),COND(50,50),
     1 SCON(50),QFACO(50),ERRT(50),FN(50,50,2),FD(50,50,2)
      COMMON/BLAD4/A(50,50),B(50),SQSRC1(50),SQSRC2(50),SQCON1(50),
     1 SQCON2(50),QVHT,QVCL,QAHT,QACL,QHZ,QINC,QTRAN
```

```
      COMMON/BLAD5/DELT1,DELT,TIME,SUMKT,QCIN,QCINO,FAC,FRAC,
     1 PI,TIMEX,DEGRAD,TBASE,DD,TMAX,TMIN,TBAR,FACI,REMAIN
      COMMON/BLAD6/QSRC(50),QCON(50),QC12(100),SQC121(100),
     1 SQC122(100),TCMIN,TCMAX,TCMINN,TCMIND,TCMAXN,TCMAXD,DTCOOL
      COMMON/BLAD7/TPRDAY,SBCON,TAMB,QCINT,PRINTH,PRINTD,PRINTM
      COMMON/BLAD8/IDAY,IDPRYR,INDAY,KDATA,QHCONV,ALAT,DLONG,
     1 RINDEX,TOLT,DEC,COSDEC,SINDEC,SINLAT,COSLAT,QSP
     2 ,HRCRIT,QICUT,TMORN,TEVEN,KSHUT,KCOOL,MOSH1,MOSH2
      COMMON/BLAD9/TAD(50),VELD(50),QHD(50),NJS,ISOL(15),
     1 TILT(15),WAZIM(15),AGLZ(15),NGLZ(15),NJA,IAMB(10),
     2 ALFA(15),OHANG(15),OSEPR(15),TGLZ(15),DABS(15)
      COMMON/BLAD10/QDNMAX,RDIFF(15),EX,RHO,TZERO,
     1 NCONN,I1CON(100),I2CON(100),U(100),ACON(100),UD(100),UN(100)
      COMMON/BLAD11/TILTC,AZIMC,RHOC,COSTC,SINTC,FSSC,FSGC,RESNI,
     1 JCP,KND,QDH(24),QFH(24)
      COMMON/TROMBE/VOLF,RCON(50),KVENT,IAIR,JAIR,RLNGTH,RHOSR,
     1 ASPRAT,FCSR,JWA,TRCOAT,IO1,IO2,KWALL,NHOUR,ULOAD,IDAT
      DIMENSION QHOQD(10,7),XHRS(10)
C
      INTEGER DAY,DAY1,DAY2,YR,DATE,UNITS,PRINTH,PRINTD,PRINTM
C

      DATA XHRS/60.,67.5,75.,82.5,90.,97.5,105.,112.5,120.,0./
      DATA AX,BX,RX/0.41,0.37,1.0/
      DATA QHOQD/.198,.180,.165,.152,.142,.133,.124,.117,
     , .109,0.,
     +.164,.155,.145,.135,.128,.121,.114,.108,
     , .102,0.,
     +.103,.108,.110,.108,.105,.102,.099,.096,
     , .093,0.,
     +.033,.052,.065,.072,.096,.078,.078,.078,
     , .077,0.,
     +0.,0.,.020,.032,.040,.048,.052,.055,.058,0.,
     +0.,0.,0.,.005,.011,.019,.026,.037,.037,0.,
     +5*0.,.003,.008,.013,.018,0./
      DG=DEGRAD
C -- READ DATA FOR EACH OF 24 HOURS FROM TAPE1
C -- IF KDATA IS NON-ZERO QHD IS RECALCULATED FROM CLEAR-DAY EQUATIONS
C --- TAD IS AMBIENT TEMPERATURE (DEG.F)
C --- VELD IS WIND VELOCITY (MPH)
C --- QHD IS SOLAR RADIATION INTENSITY
C --- KCTY IS 1 FOR LOS ALAMOS (NOS FILE LAL7273, AND LAL7677)
C --- (FOR THESE FILES DATA STARTS AT TIME 0, AND IS IN HOURLY
C ---  INCREMENTS FOR LOCAL STANDARD TIME)
C
C
   70 CONTINUE
      GO TO (80,90),IDAT
   80 CONTINUE
      READ(1,3030) DATE,(TAD(IH),IH=1,24)
      IF(DATE.EQ.0) GO TO 80
      READ(1,3030) IDATE1,(VELD(IH),IH=1,24)
      READ(1,3030) IDATE2,(QDH(IH),IH=1,24)
      READ(1,3030) IDATE3,(QFH(IH),IH=1,24)
      GO TO 95
```

```
 90 CONTINUE
    READ(5,3030) DATE,(TAD(IH),IH=1,24)
    IF(DATE.EQ.0) GO TO 90
    READ(5,3030) IDATE1,(VELD(IH),IH=1,24)
    READ(5,3030) IDATE2,(QDH(IH),IH=1,24)
    READ(5,3030) IDATE3,(QFH(IH),IH=1,24)
 95 YR=MOD(DATE,100)
    KMON=DATE/10000
    KDAY=DATE/100-KMON*100
    IF(MTIME.EQ.0) GO TO 121
    IF(KDAY.NE.DAY.OR.KMON.NE.MO) GO TO 150
121 CONTINUE
    IF(MTIME.GT.0) GO TO 220
    IF(DATE.NE.INDATE) GO TO 70
    GO TO 220
150 PRINT 151,DAY,KDAY,MO,KMON
151 FORMAT(/39H WEATHER DATA ERROR IN SUBROUTINE DAYLY/
   1 5H DAY=,I2,8H   KDAY=,I2,6H   MO=,I2,8H   KMON=,I2)
    STOP
220 CONTINUE
C
    TMAX=0.
    TMIN=1.E6
    TBAR=0.
    DO 240 IH=1,24
    IF(TAD(IH).GT.TMAX) TMAX=TAD(IH)
          IF(TAD(IH).LT.TMIN) TMIN=TAD(IH)

    TBAR=TBAR+TAD(IH)
240 CONTINUE
    DDEG=TBASE-.5*(TMAX+TMIN)
    DD=DD+AMAX1(DDEG,0.)
    TBAR=TBAR/24.
C
C -- DECLINATION
    ADEC=FLOAT(MO-1)+FLOAT(DAY)/32.
    DEC=23.279*COS(DG*30.*(ADEC-5.7))

    SINDEC=SIN(DG*DEC)
    COSDEC=COS(DG*DEC)
    HRCRIT=90.
    IF(DEC.LE.0.) GO TO 280
    HRCRIT=-90.
    CHRCR=TAN(DG*DEC)/TAN(DG*ALAT)
    IF(CHRCR.GT.1.) GO TO 280
    HRCRIT=ARCOS(CHRCR)/DG
280 CONTINUE
C -- SOLAR CONSTANT
    GO TO(310,320),UNITS
310 QSP=426.98-13.50*SIN(DG*360.*(272.1+FLOAT(IDAY))/365.)
    GO TO 330
320 QSP=1346.1-42.56*SIN(DG*360.*(272.1+FLOAT(IDAY))/365.)
330 CONTINUE
    IF(KDATA.EQ.0) GO TO 1000
C -- CLEAR DAY CALCULATIONS FOR TOTAL HORIZONTAL INSOLATION
```

```
      NHRSR=9
C --  SUNRISE HOUR ANGLE (DEG)
      HRSR=ARCOS(-TAN(DG*ALAT)*TAN(DG*DEC))/DG
C --  DAYLY EXTRATERRESTRIAL RADIATION (BTU/SQ.FT)
      XDAY=IDAY
      DER=428.*24./PI*(1.+.033*COS(2.*PI*XDAY/365.))*(COSLAT*COSDEC
     1 *SIN(DG*HRSR)+HRSR*DG*SINLAT*SINDEC)
C --  DAYLY TOTAL HORIZONTAL RADIATION (BTU/SQ.FT)
      DTHR=DER*(AX+BX*RX)
C --  LOCATION IN TABLES FOR HOURLY/DAYLY RADIATION RATIO
      DO 400 L=2,NHRSR
      IF(XHRS(L).GT.HRSR) GO TO 410
  400 CONTINUE
      L=NHRSR
  410 LO=L-1
      FRAX=(HRSR-XHRS(LO))/(XHRS(L)-XHRS(LO))
C --  HOURLY HORIZONTAL RADIATION (BTUH/SQ.FT)
      DO 450 IH=1,24
      QHD(IH)=0.
      J=(IABS(25-2*(IH-1))+1)/2
      IF(J.GT.7) GO TO 450
      XRAT=QHOQD(LO,J)+FRAX*(QHOQD(L,J)-QHOQD(LO,J))
      QHD(IH)=XRAT*DTHR
      IF(QHD(IH).LT.0.) QHD(IH)=0
  450 CONTINUE
 1000 CONTINUE
      RETURN
C
 3030 FORMAT(1X,I6,24F3.0)
      END
            SUBROUTINE SUNSRC
      COMMON/BLAD1/NV,NF,NT,NMAX,KF(50),IC,LV(50),LF(50),LT(50),
     1 KICHNG,KIC,ITMAX,NERR,UNITS,KAUXCL,KCTY,KCALC,KDELT,KCONU
      COMMON/BLAD2/NTIME,MTIME,ITIME,DATE,DAY,DAY1,DAY2,NDAY(12),
     1 MO,MO1,YR,NMO,NDAY1,INDATE,IPRSM,KHEDPR
      COMMON/BLAD3/T(50),TO(50),CPM(50),S(50),SP(50),COND(50,50),
     1 SCON(50),QFACO(50),ERRT(50),FN(50,50,2),FD(50,50,2)
      COMMON/BLAD4/A(50,50),B(50),SQSRC1(50),SQSRC2(50),SQCON1(50),
     1 SQCON2(50),QVHT,QVCL,QAHT,QACL,QHZ,QINC,QTRAN
      COMMON/BLAD5/DELT1,DELT,TIME,SUMKT,QCIN,QCINO,FAC,FRAC,
     1 PI,TIMEX,DEGRAD,TBASE,DD,TMAX,TMIN,TBAR,FACI,REMAIN
      COMMON/BLAD6/QSRC(50),QCON(50),QC12(100),SQC121(100),
     1 SQC122(100),TCMIN,TCMAX,TCMINN,TCMIND,TCMAXN,TCMAXD,DTCOOL
      COMMON/BLAD7/TPRDAY,SBCON,TAMB,QCINT,PRINTH,PRINTD,PRINTM
      COMMON/BLAD8/IDAY,IDPRYR,INDAY,KDATA,QHCONV,ALAT,DLONG,
     1 RINDEX,TOLT,DEC,COSDEC,SINDEC,SINLAT,COSLAT,QSP
     2 ,HRCRIT,QICUT,TMORN,TEVEN,KSHUT,KCOOL,MOSH1,MOSH2
      COMMON/BLAD9/TAD(50),VELD(50),QHD(50),NJS,ISOL(15),
     1 TILT(15),WAZIM(15),AGLZ(15),NGLZ(15),NJA,IAMB(10),
     2 ALFA(15),OHANG(15),OSEPR(15),TGLZ(15),DABS(15)
      COMMON/BLAD10/QDNMAX,RDIFF(15),EX,RHO,TZERO,
     1 NCONN,I1CON(100),I2CON(100),U(100),ACON(100),UD(100),UN(100)
      COMMON/BLAD11/TILTC,AZIMC,RHOC,COSTC,SINTC,FSSC,FSGC,RESNI,

     1 JCP,KND,QDH(24),QFH(24)
```

```
      COMMON/TROMBE/VOLF,RCON(50),KVENT,IAIR,JAIR,RLNGTH,RHOSR,
     1 ASPRAT,FCSR,JWA,TRCOAT,IO1,IO2,KWALL,NHOUR,ULOAD,IDAT
      DIMENSION EOT(12)
C
      INTEGER DAY,DAY1,DAY2,YR,DATE,UNITS,PRINTH,PRINTD,PRINTM
C
      DATA EOT/-11.2,-13.9,-7.5,1.1,3.3,-1.4,-6.2,-2.4,7.5,
     1 15.4,13.8,1.6/
      DATA A1,B1/1.79,0.55/
C
      DG=DEGRAD
      SUNDAT=IDAT
       IF(SUNDAT.GT.0.) GO TO 97
      QH=QHD(ITIME)*QHCONV
   97  CONTINUE
       QH=QDH(ITIME)+QFH(ITIME)
      TAMB=TAD(ITIME)
      WVEL=VELD(ITIME)
      IA=IAMB(1)
      T(IA)=TAMB
C -- SOLAR HEAT SOURCE
      IF(NJS.LE.0) RETURN
      DO 140 I=1,NMAX
      S(I)=0.
  140 SP(I)=0.
      QHZ=0.
      QINC=0.
      QTRAN=0.
      JDIF=0
      KSHUTI=KSHUT
      IF(QICUT.GE.0.0.AND.RESNI.GT.0.01) KSHUT=KCOOL
      IF(QH.LE.1.) RETURN
      QHZ=QH
C -- SOLAR TIME AND HOUR ANGLE
C ************************************************************
C THE LINE BELOW IS ADDED
C************************************************************
      SUNTIM=ITIME+EOT(MO)/60.-DLONG/15.
      IF(KDATA.NE.0) SUNTIM=TIMEX-0.5
      HR=15.*(12.-SUNTIM)
      COSHR=COS(DG*HR)
      SINHR=SIN(DG*HR)
C -- SUN ALTITUDE
      SINALT=COSLAT*COSDEC*COSHR+SINLAT*SINDEC
      IF(SINALT.GT.0..AND.QH.GT.10.) GO TO 150
      QDN=0.
      QDER=0.
      JDIF=1
      GO TO 180
  150 ALT=ARSIN(SINALT)
      COSALT=COS(ALT)
C -- SUN AZIMUTH
      SINAZI=COSDEC*SINHR/COSALT
      AZIM=ARSIN(SINAZI)
           IF(ABS(HR).GT.HRCRIT) AZIM=(PI-ABS(AZIM))*AZIM/ABS(AZIM)
```

```
C -- PYRANOMETER INPUT DATA
C -- CORRELATION FOR DIRECT NORMAL RADIATION AS A FUNCTION OF TOTAL
C -- HORIZONTAL.  BOES CORRELATION USED HERE.  SAME USED IN SUB. COLLCT
C -- TO OBTAIN TOTAL HORIZ. WHEN DATA IS TAKEN ON TILT (TILTC).
        IF(SUNDAT.GT.0.) GO TO 171
      IF(TILTC.LE.1.0) GO TO 160
      CALL COLLCT(QH,AZIM,SINALT,COSALT,PP,AZIMC,SINTC,COSTC,
     1 FSSC,FSGC,RHOC,QDNMAX,QSP,A1,B1)
      GO TO 170
  160 CONTINUE
      QEXT=QSP*SINALT
      PP=QH/QEXT
  170 FQDN=A1*PP-B1
      IF(FQDN.LT.0.) FQDN=0.

      IF(FQDN.GT.1.) FQDN=1
      QDN=FQDN*QDNMAX
      QDER=QDN*SINALT
  180 QDIF=QH-QDER
  171  QDN=QDH(ITIME)/SINALT
       QDIF=QFH(ITIME)
       QDER=QDN*SINALT
C
C -- SOLAR HEAT SOURCE NODES
      DO 600 J=1,NJS
      I=ISOL(J)
      WAZI=WAZIM(J)
      NGL=NGLZ(J)
      SINTLT=SIN(DG*TILT(J))
      COSTLT=COS(DG*TILT(J))
      IF(JDIF.EQ.0) GO TO 190
      QDNA=0.
      QINSR=0.
      TRANS=0.
      GLABS=0.
      COSINC=0.
      GO TO 380
C -- WALL-SOLAR AZIMUTH
  190 GAM=AZIM-DG*WAZI
      COSGAM=COS(GAM)
C -- WALL-SOLAR ANGLE OF INCIDENCE
      COSINC=COSALT*SINTLT*COSGAM+SINALT*COSTLT
      IF(COSINC.LE.0.) COSINC=.0001
      AINC=ARCOS(COSINC)
C -- SHADING FROM 1-D OVERHANG
      AFACT=1.0
      IF(OHANG(J).LE.0.) GO TO 340
      TANEFF=SINALT/COSALT/COSGAM
      IF(TANEFF.LT.OSEPR(J)/OHANG(J)) GO TO 340
      AFACT=1.-(OHANG(J)*TANEFF-OSEPR(J))/(SINTLT+COSTLT*TANEFF)
      IF(AFACT.GT.1.0) AFACT=1.0
      IF(AFACT.LT.0.) AFACT=0
  340 QDNA=QDN*AFACT
C
C -- SPECULAR REFLECTOR (HORIZONTAL WITH VERTICAL COLLCTOR)
```

```
      QINSR=0.
      IF(RLNGTH.EQ.0.0.OR.RHOSR.EQ.0.) GO TO 380
      IF(J.NE.1) GO TO 380
      IF(ABS(GAM).GE.PI/2.) GO TO 380
      TANGAM=ABS(TAN(GAM))
      RLEFF=COSGAM*COSALT/SINALT
      IF(RLEFF.GT.RLNGTH) RLEFF=RLNGTH
      DWOW=RLEFF*TANGAM/ASPRAT
      ASR=RLEFF*(1.-.5*DWOW)
      IF(DWOW.GT.1.) ASR=.5*ASPRAT/TANGAM
      QINSR=QDN*ASR*RHOSR*SINALT
 380  CONTINUE
C
C -- INCIDENT SOLAR RADIATION
      QINDN=QDNA*COSINC
      QINDF=QDIF*.5*(1.+COSTLT)
      QINRF=QH*RHO*(.5*(1.-COSTLT)-FCSR)+QDIF*FCSR*RHOSR
      QBEAM=QINDN+QINSR
      QDIFF=QINDF+QINRF
          QINC=QBEAM+QDIFF
C
      IF(J.NE.1) GO TO 386
      KSHUT=KSHUTI
      IF(QINC.LT.QICUT.AND.RESNI.GT.0.01) KSHUT=KCOOL
      IF(KSHUT.EQ.1) RETURN
 386  QTRAN=QINC
      IF(NGL.LE.0) GO TO 490
C
C -- TRANSMITTED SOLAR RADIATION
C

      IF(JDIF.GT.0) GO TO 392
      CALL GLOSS(NGL,AINC,RINDEX,EX,TGLZ(J),TRANS,GLABS)
 392  CONTINUE
      QQ1=QBEAM
      QQ2=QDIFF
      XYZ=1./FLOAT(NGL)
      TAUDR=TRANS**XYZ
      TAUDF=(1.-RDIFF(J))**XYZ
      LLL=NGL+JWA+2
      DO 450 IX=1,NGL
      QIN1=QQ1*TAUDR
      QIN2=QQ2*TAUDF
      QQ1=QIN1*GLABS
      QQ2=QIN2*(1.-DABS(J))
      IF(J.NE.1)GO TO 450
C -- ABSORBED RADIATION HEAT SOURCES
      LL=LLL-IX
      IG=I1CON(LL)
      QABS=QIN1*(1.-GLABS)+QIN2*DABS(J)
      IF(IX.EQ.NGL) QABS=QABS+(QQ1+QQ2)*(1.-TRCOAT)
      S(IG)=S(IG)+QABS*AGLZ(J)
 450  CONTINUE
      QTRAN=(QQ1+QQ2)*TRCOAT
 490  CONTINUE
```

```
C --
      S(I)=S(I)+QTRAN*AGLZ(J)*ALFA(J)
C
  600 CONTINUE
      RETURN
      END
       SUBROUTINE GLOSS(NGL,AINC,RINDEX,EX,TGLZ,TRANS,GLABS)
C -- FRESNEL RELATION FOR REFLECTION
      TRANS=1.
      AREF=0.
      IF(NGL.EQ.0) GO TO 230
      NGF=2*NGL-1
      IF(AINC.EQ.0.) GO TO 200
      AREF=ARSIN(SIN(AINC)/RINDEX)
      X=AINC-AREF
      Y=AINC+AREF
      R1=(SIN(X)/SIN(Y))**2
      R2=(TAN(X)/TAN(Y))**2
      T1=(1.-R1)/(1.+R1*NGF)
      T2=(1.-R2)/(1.+R2*NGF)
      TRANS=0.5*(T1+T2)
      GO TO 230
  200 R=((RINDEX-1.)/(RINDEX+1.))**2
      TRANS=(1.-R)/(1.+R*NGF)
  230 CONTINUE
C -- ABSORBTION IN GLAZING
      GLABS=EXP(-EX*TGLZ/COS(AREF))
      RETURN
      END
       SUBROUTINE COLLCT(QH,AZIM,SINALT,COSALT,PP,AZIMC,SINTC,COSTC,
     1 FSSC,FSGC,RHOC,QDNMAX,QSP,A1,B1)
C
      DEGRAD=3.141592654/180.
      XMIN=B1/A1
      XMAX=(1.+B1)/A1
      GAMC=AZIMC*DEGRAD-AZIM
      COSIC=COSALT*SINTC*COS(GAMC)+SINALT*COSTC
      IF(COSIC.LE.0.) COSIC=.0001
      RATIO=SINALT/COSIC
      CAPA=QDNMAX/QSP*(1.-FSSC*RATIO)
      CAPB=RATIO*(FSSC+RHOC*FSGC)
      Y=QH/QSP/COSIC
      PP=(Y+B1*CAPA)/(A1*CAPA+CAPB)
      IF(PP.LT.XMIN) PP=Y/CAPB
      IF(PP.GT.XMAX) PP=(Y-CAPA)/CAPB
      QH=PP*QSP*SINALT

      RETURN
      END
       SUBROUTINE MCFLSS(NDA,N,A,B)
C -- TO SOLVE SET OF N LINEAR EQUATIONS - SUM(A(I,J)*X(J))=B(I)
C -- FOR N UNKNOWNS X(J).
C -- A IS N BY N MATRIX OF COEFFICIENTS, B IS ARRAY OF SOURCE TERMS.
C -- NDA IS FIRST DIMENSION OF A IN CALLING PROGRAM DIMENSION STATEMENT.
C -- RESULTING VALUES OF X(J) ARE STORED IN B ARRAY.  A ARRAY IS DESTROYED.
```

```
      DIMENSION A(NDA,1),B(1)
      DO 100 L=2,N
      LO=L-1
      IF(A(LO,LO).EQ.0.) GO TO 300
      BBL=B(LO)/A(LO,LO)
      DO 100 I=L,N
      AAL=A(I,LO)/A(LO,LO)
      B(I)=B(I)-BBL*A(I,LO)
      DO 100 J=L,N
  100 A(I,J)=A(I,J)-AAL*A(LO,J)
      LO=N
      IF(A(N,N).EQ.0.) GO TO 300
      B(N)=B(N)/A(N,N)
      N1=N-1
      DO 200 K=1,N1
      L=N-K
      J1=L+1
      SUM=0.
      DO 190 J=J1,N
  190 SUM=SUM+A(L,J)*B(J)
  200 B(L)=(B(L)-SUM)/A(L,L)
      RETURN
  300 PRINT 301,LO
  301 FORMAT(/23H $$$$$ -- DIAGONAL TERM,I3,24H OF THE A MATRIX IS ZERO,
     1 8H - $$$$$)
      STOP
```

```
PASOLE - PASSIVE SOLAR ENERGY

TROMBE WALL - PER UNIT WALL AREA - INDATE= 10168      ULOAD= 1.200

CONDUCTANCE CONNECTIONS
   J    I1   I2      UD               UN               ACON
   1     1   10   0.0              0.0              0.1000E 01
   2     1    2   0.5333E 01       0.5333E 01       0.1000E 01
   3     2    3   0.2667E 01       0.2667E 01       0.1000E 01
   4     3    4   0.2667E 01       0.2667E 01       0.1000E 01
   5     4    5   0.2667E 01       0.2667E 01       0.1000E 01
   6     5    6   0.5333E 01       0.5333E 01       0.1000E 01
   7     6    7   0.1500E 01       0.1500E 01       0.1000E 01
   8     7    8   0.1200E 01       0.1200E 01       0.1000E 01
   9     9    7   0.0              0.0              0.1000E 01
  10     1    9   0.0              0.0              0.1000E 01
  11     9   10   0.0              0.0              0.1000E 01
  12    10   11   0.0              0.0              0.1000E 01
  13    11    8   0.0              0.0              0.1000E 01

AMBIENT TEMPERATURE NODES
   I=     8
SOLAR HEAT SOURCES
   J   ISOL  NGLZ   TILT    WAZIM    ALFA     AGLZ   OHANG    OSEPR     TGLZ    DABS
   1    1     2    90.00    0.0    1.0000    1.00   0.0      0.0     0.0209  0.1413

     NMAX       IC      NTIME      NSEG      NMO      NDAY1     ITMAX     UNITS     KDAT
      50         7        24         4        12       366        30        1         0
    KWALL     KCALC     KDELT     KCONU     KCTY      NSGW     KAUXCL     KVENT
      2         1         1         0         1         0         1         2
     JCP       JWA       IAIR      JAIR
      8        10         9         9

     QHCONV        ALAT          OLONG         RINDEX        TMORN         TEVEN
  0.1000E 01    0.4226E 02    0.7800E 01    0.1526E 01    0.7000E 01    0.1700E 02
     TZERO         QDNMAX        RHO           EX            FAC           TOLT
  0.4600E 03    0.3172E 03    0.3000E 00    0.6000E 01    0.5000E 00    0.1000E 01
     TCMINN        TCMIND        TILTC         AZIMC         RHOC          FACI
  0.6800E 02    0.6800E 02    0.0           0.0           0.3000E 00    0.5000E 00
     TCMAXD        THCON         THICK         VOLSP         ULOAD         RESNI
 0.78000E 02   0.10000E 01   0.15000E 01   0.30000E 02   0.12000E 01   0.0
     RLNGTH        RHOSR         ASPRAT        FCSR          CPMR          RSMWI
 0.0           0.0           0.5000E 01    0.0           0.4500E 02    0.0

DATE=  12568

TIME=  0.0    ITER= 2    I280= 1    QCIN=  73.04
NODE TEMPERATURES, T(I)
 56.57   60.91   65.21   66.69   67.11   67.31   68.00    8.00   47.15   37.53
 13.75
NODE SOURCES, S(I)
  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 13.73 -23.16 -11.46  -3.94   -1.13   -1.04   -1.04   72.00    0.0     9.42
  9.42  23.16  23.16

TIME=  1.0    ITER= 1    I280= 1    QCIN=  74.28
NODE TEMPERATURES, T(I)
 55.73   59.94   64.55   66.42   67.08   67.28   68.00    7.00   46.59   37.26
 14.21
NODE SOURCES, S(I)
  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 13.32 -22.46 -12.29  -4.98   -1.75   -1.08   -1.08   73.20    0.0     9.14
  9.14  22.46  22.46

TIME=  2.0    ITER= 2    I280= 1    QCIN=  73.18
NODE TEMPERATURES, T(I)
 55.10   59.11   63.92   66.12   67.00   67.22   68.00    8.00   46.39   37.48
 15.41
NODE SOURCES, S(I)
  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 12.65 -21.37 -12.82  -5.87   -2.34   -1.18   -1.18   72.00    0.0     8.72
  8.72  21.37  21.37
```

```
TIME=  3.0    ITER= 2    I280= 1    QCIN=  75.72
NODE TEMPERATURES, T(I)
 54.20  58.34  63.31  65.80  66.87  67.12  68.00   6.00  45.16  35.93
 13.08
NODE SOURCES, S(I)
  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 13.02 -22.07 -13.27  -6.62  -2.88  -1.32  -1.32  74.40   0.0    9.04
  9.04  22.06  22.06

TIME=  4.0    ITER= 1    I280= 1    QCIN=  74.70
NODE TEMPERATURES, T(I)
 53.49  57.59  62.73  65.46  66.72  67.00  68.00   7.00  44.53  35.39
 12.75
NODE SOURCES, S(I)
  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 12.90 -21.86 -13.72  -7.27  -3.37  -1.50  -1.50  73.20   0.0    8.96
  8.96  21.86  21.86

TIME=  5.0    ITER= 2    I280= 1    QCIN=  74.90
NODE TEMPERATURES, T(I)
 53.03  56.92  62.17  65.11  66.54  66.86  68.00   7.00  44.51  35.80
 14.20
NODE SOURCES, S(I)
  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 12.23 -20.76 -13.99  -7.83  -3.83  -1.70  -1.70  73.20   0.0    8.52
  8.52  20.76  20.76

TIME=  6.0    ITER= 2    I280= 1    QCIN=  72.74
NODE TEMPERATURES, T(I)
 52.63  56.36  61.64  64.75  66.35  66.71  68.00   9.00  44.45  36.11
 15.39
NODE SOURCES, S(I)
  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 11.73 -19.91 -14.07  -8.29  -4.26  -1.94  -1.94  70.80   0.0    8.18
  8.18  19.91  19.91

TIME=  7.0    ITER= 1    I280= 1    QCIN=  75.39
NODE TEMPERATURES, T(I)
 52.08  55.84  61.14  64.39  66.13  66.54  68.00   7.00  43.85  35.44
 14.58
NODE SOURCES, S(I)
  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 11.81 -20.05 -14.13  -8.67  -4.65  -2.19  -2.19  73.20   0.0    8.23
  8.23  20.04  20.04

TIME=  8.0    ITER= 2    I280= 1    QCIN=  75.64
NODE TEMPERATURES, T(I)
 66.92  58.03  60.93  64.06  65.91  66.37  68.00   7.00  59.48  51.88
 23.39
NODE SOURCES, S(I)
 66.54   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   10.57
 13.67
CONNECTION HEAT FLOW RATE, QC12(J)
 11.67  47.42  -7.72  -8.36  -4.94  -2.44  -2.44  73.20   0.0    7.44
  7.44  29.68  43.35

TIME=  9.0    ITER= 4    I280= 1    QCIN=  51.20
NODE TEMPERATURES, T(I)
 80.34  64.05  61.53  63.85  65.70  66.21  68.00  11.00  68.62  65.57
 30.97
NODE SOURCES, S(I)
125.71   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   19.10
 24.23
CONNECTION HEAT FLOW RATE, QC12(J)
 12.36  86.92   6.71  -6.20  -4.93  -2.69  -2.69  68.40  19.89  26.44
  6.55  38.01  62.24

TIME= 10.0    ITER= 3    I280= 1    QCIN=   9.28
NODE TEMPERATURES, T(I)
```

```
 90.73   71.26   63.15   63.90   65.54   66.08   68.00   15.00   69.41   70.29
 33.32
NODE SOURCES, S(I)
176.57    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    25.83
 32.43
CONNECTION HEAT FLOW RATE, QC12(J)
 17.73 103.81   21.63   -2.00   -4.36   -2.88   -2.88   63.60   57.21   55.03
 -2.17   41.39   73.82

TIME= 11.0   ITER= 2   I280= 1   QCIN=   0.0
NODE TEMPERATURES, T(I)
 92.13   74.74   64.49   64.12   65.49   66.04   68.00   17.00   69.49   71.04
 35.78
NODE SOURCES, S(I)
169.29    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    24.47
 30.74
CONNECTION HEAT FLOW RATE, QC12(J)
 18.47   92.76   27.34    0.97   -3.66   -2.93   -2.93   61.20   65.47   61.33
 -3.97   39.52   62.86

TIME= 11.0   ITER= 2   I280= 2   QCIN=   0.0
NODE TEMPERATURES, T(I)
 93.56   77.04   65.50   64.33   65.50   66.30   69.13   17.00   70.63   72.33
 37.78
NODE SOURCES, S(I)
169.29    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    24.47
 30.74
CONNECTION HEAT FLOW RATE, QC12(J)
 18.73   88.12   30.78    3.13   -3.13   -4.25   -4.25   62.55   66.80   62.44
 -4.36   38.84   69.58

TIME= 12.0   ITER= 2   I280= 1   QCIN=   0.0
NODE TEMPERATURES, T(I)
103.20   82.71   68.10   65.07   65.97   68.16   75.96   19.00   77.63   80.21
 42.81
NODE SOURCES, S(I)
203.63    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    29.07
 36.32
CONNECTION HEAT FLOW RATE, QC12(J)
 21.27 109.25   38.97    8.08   -2.39 -11.70  -11.70   68.35   80.06   73.10
 -6.96   43.38   79.70

TIME= 13.0   ITER= 2   I280= 1   QCIN=   0.0
NODE TEMPERATURES, T(I)
105.54   87.98   70.93   66.18   66.86   69.24   77.68   20.00   79.40   82.23
 46.41
NODE SOURCES, S(I)
189.79    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    27.47
 34.41
CONNECTION HEAT FLOW RATE, QC12(J)
 21.81   93.68   45.46   12.67   -1.82 -12.66  -12.66   69.21   81.87   74.30
 -7.58   41.71   76.12

TIME= 14.0   ITER= 2   I280= 1   QCIN=   0.0
NODE TEMPERATURES, T(I)
103.33   91.00   73.71   67.57   67.75   69.56   76.01   21.00   77.67   79.44
 43.78
NODE SOURCES, S(I)
158.90    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    23.70
 29.87
CONNECTION HEAT FLOW RATE, QC12(J)
 22.05   65.78   46.10   16.37   -0.48   -9.67   -9.67   66.01   75.68   71.06
 -4.62   41.13   71.00

TIME= 15.0   ITER= 2   I280= 1   QCIN=   0.0
NODE TEMPERATURES, T(I)
 95.58   91.13   76.00   69.06   68.35   68.77   70.28   21.00   71.75   71.27
 36.11
NODE SOURCES, S(I)
107.77    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0    16.77
 21.45
CONNECTION HEAT FLOW RATE, QC12(J)
 21.49   23.70   40.35   18.51    1.90   -2.26   -2.26   59.14   61.40   62.58
  1.18   39.44   60.89

TIME= 16.0   ITER= 2   I280= 1   QCIN=   0.0
NODE TEMPERATURES, T(I)
 92.23   90.38   76.22   69.28   68.32   68.25   68.00   20.00   69.38   68.25
 34.60
NODE SOURCES, S(I)
```

```
 1.15    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.19
 0.25
CONNECTION HEAT FLOW RATE, QC12(J)
 20.86    9.88   37.76   18.50    2.56    0.38    0.38   57.60   58.69   60.50
  2.85   37.28   55.54

TIME= 16.0   ITER= 3   I280= 2   QCIN=  51.44
NODE TEMPERATURES, T(I)
 80.13   87.03   77.22   70.36   68.56   68.43   68.00   20.00   68.28   59.25
 28.64
NODE SOURCES, S(I)
 1.15    0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.19
 0.25
CONNECTION HEAT FLOW RATE, QC12(J)
 17.14  -36.81   26.17   18.28    4.83    0.65    0.65   57.60    5.51   20.82
 15.31   32.64   32.89

TIME= 17.0   ITER= 3   I280= 1   QCIN=  60.06
NODE TEMPERATURES, T(I)
 76.82   82.34   77.44   71.39   68.98   68.76   68.00   17.00   65.56   54.07
 25.80
NODE SOURCES, S(I)
 0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 18.22  -29.48   13.08   16.12    6.44    1.14    1.14   61.20    0.0    11.26
 11.26   29.48   29.48

TIME= 18.0   ITER= 2   I280= 1   QCIN=  60.70
NODE TEMPERATURES, T(I)
 73.58   78.94   76.96   72.09   69.45   69.13   68.00   16.00   62.53   51.25
 23.52
NODE SOURCES, S(I)
 0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 17.58  -28.63    5.29   12.99    7.04    1.70    1.70   62.40    0.0    11.04
 11.04   28.63   28.63

TIME= 19.0   ITER= 2   I280= 1   QCIN=  61.38
NODE TEMPERATURES, T(I)
 71.24   76.24   76.18   72.48   69.89   69.48   68.00   15.00   60.88   50.31
 24.26
NODE SOURCES, S(I)
 0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 16.33  -26.69    0.15    9.87    6.90    2.22    2.22   63.60    0.0    10.36
 10.36   26.69   26.69

TIME= 20.0   ITER= 2   I280= 1   QCIN=  63.35
NODE TEMPERATURES, T(I)
 69.00   74.01   75.29   72.65   70.27   69.77   68.00   13.00   58.54   47.87
 21.58
NODE SOURCES, S(I)
 0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 16.28  -26.73   -3.40    7.05    6.35    2.65    2.65   66.00    0.0    10.46
 10.46   26.73   26.73

TIME= 21.0   ITER= 2   I280= 1   QCIN=  64.22
NODE TEMPERATURES, T(I)
 67.31   72.10   74.35   72.63   70.55   69.99   68.00   12.00   57.25   46.99
 21.67
NODE SOURCES, S(I)
 0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 15.53  -25.59   -6.00    4.59    5.57    2.98    2.98   67.20    0.0    10.06
 10.06   25.59   25.59

TIME= 22.0   ITER= 2   I280= 1   QCIN=  64.01
NODE TEMPERATURES, T(I)
 65.83   70.48   73.42   72.49   70.73   70.13   68.00   12.00   56.04   46.04
 21.38
NODE SOURCES, S(I)
 0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 0.0
CONNECTION HEAT FLOW RATE, QC12(J)
```

```
 15.02 -24.81  -7.85    2.49    4.70    3.19    3.19  67.20    0.0     9.79
  9.79  24.81  24.81

TIME= 23.0    ITER= 2    I280= 1    QCIN=  62.70
NODE TEMPERATURES, T(I)
 64.63   69.08  72.52  72.25   70.82   70.20   68.00   13.00   55.24   45.66
 21.97
NODE SOURCES, S(I)
  0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  0.0
CONNECTION HEAT FLOW RATE, QC12(J)
 14.34 -23.73  -9.18    0.72    3.82    3.30    3.30   66.00    0.0     9.39
  9.39  23.73  23.73

MONTH INDEX=  1      MONTH OF YEAR=  1
    QVHT             QVCL          QAHT            QACL             DD
 0.0          -0.9098E 02  0.3938E 05  0.0               0.1360E 04

    I     SQSRC1           SQSRC2              SQCON1          SQCON2
    1  0.1470E 05   0.0                  0.6272E 00 -0.1498E 05
    2  0.0          0.0                  0.5499E 04 -0.5553E 04
    3  0.0          0.0                  0.2332E 04 -0.2411E 04
    4  0.0          0.0                  0.1124E 04 -0.1189E 04
    5  0.0          0.0                  0.6568E 03 -0.6997E 03
    6  0.0          0.0                  0.1298E 00 -0.1227E 01
    8  0.0          0.0                  0.5970E 05  0.0
    9  0.0          0.0                  0.2333E 01 -0.6124E 02
   10  0.2194E 04   0.0                  0.7541E-02 -0.2233E 04
   11  0.2791E 04   0.0                  0.1029E-01 -0.2933E 04
    7  0.0          0.0                  0.1642E 03 -0.3942E 05
MONTH INDEX=  2      MONTH OF YEAR=  2
    QVHT             QVCL          QAHT            QACL             DD
 0.0          -0.8506E 03  0.7075E 05  0.0               0.2541E 04

    I     SQSRC1           SQSRC2              SQCON1          SQCON2
    1  0.3476E 05   0.0                  0.7783E 00 -0.3511E 05
    2  0.0          0.0                  0.1205E 05 -0.1203E 05
    3  0.0          0.0                  0.5193E 04 -0.5252E 04
    4  0.0          0.0                  0.2527E 04 -0.2582E 04
    5  0.0          0.0                  0.1461E 04 -0.1492E 04
    6  0.0          0.0                  0.6132E 00 -0.1228E 01
    8  0.0          0.0                  0.1173E 06  0.0
    9  0.0          0.0                  0.2318E 02 -0.7240E 02
   10  0.5276E 04   0.0                  0.1243E-01 -0.5321E 04
   11  0.6751E 04   0.0                  0.2379E-01 -0.6871E 04
    7  0.0          0.0                  0.9432E 03 -0.7081E 05
MONTH INDEX=  3      MONTH OF YEAR=  3
    QVHT             QVCL          QAHT            QACL             DD
 0.0          -0.2473E 04  0.9157E 05  0.0               0.3368E 04

    I     SQSRC1           SQSRC2              SQCON1          SQCON2
    1  0.5391E 05   0.0                  0.9188E 00 -0.5428E 05
    2  0.0          0.0                  0.1798E 05 -0.1782E 05
    3  0.0          0.0                  0.7883E 04 -0.7820E 04
    4  0.0          0.0                  0.3963E 04 -0.3916E 04
    5  0.0          0.0                  0.2353E 04 -0.2305E 04
    6  0.0          0.0                  0.7357E 00 -0.1229E 01
    8  0.0          0.0                  0.1623E 06  0.0
    9  0.0          0.0                  0.3296E 02 -0.8428E 02
   10  0.8349E 04   0.0                  0.1070E 00 -0.8391E 04
   11  0.1082E 05   0.0                  0.1254E 02 -0.1090E 05
    7  0.0          0.0                  0.2595E 04 -0.9164E 05
MONTH INDEX=  4      MONTH OF YEAR=  4
    QVHT             QVCL          QAHT            QACL             DD
 0.0          -0.4796E 04  0.1002E 06 -0.4361E 02  0.3797E 04

    I     SQSRC1           SQSRC2              SQCON1          SQCON2
    1  0.7120E 05   0.0                  0.1245E 01 -0.7139E 05
    2  0.0          0.0                  0.2288E 05 -0.2271E 05
    3  0.0          0.0                  0.1014E 05 -0.1007E 05
    4  0.0          0.0                  0.5279E 04 -0.5232E 04
    5  0.0          0.0                  0.3272E 04 -0.3226E 04
    6  0.0          0.0                  0.8569E 00 -0.1229E 01
    8  0.0          0.0                  0.1922E 06 -0.1984E 01
    9  0.0          0.0                  0.5122E 02 -0.9585E 02
   10  0.1120E 05   0.0                  0.3572E 00 -0.1121E 05
   11  0.1471E 05   0.0                  0.5839E 02 -0.1470E 05
```

| | | | | |
|---|---|---|---|---|
| 7 | 0.0 | 0.0 | 0.5004E 04 | -0.1003E 06 |

MONTH INDEX= 5 MONTH OF YEAR= 5

| QVHT | QVCL | QAHT | QACL | DD |
|---|---|---|---|---|
| 0.0 | -0.5628E 04 | 0.1056E 06 | -0.3161E 03 | 0.4084E 04 |

| I | SQSRC1 | SQSRC2 | SQCON1 | SQCON2 |
|---|---|---|---|---|
| 1 | 0.8515E 05 | 0.0 | 0.1703E 01 | -0.8524E 05 |
| 2 | 0.0 | 0.0 | 0.2669E 05 | -0.2650E 05 |
| 3 | 0.0 | 0.0 | 0.1194E 05 | -0.1185E 05 |
| 4 | 0.0 | 0.0 | 0.6394E 04 | -0.6335E 04 |
| 5 | 0.0 | 0.0 | 0.4124E 04 | -0.4064E 04 |
| 6 | 0.0 | 0.0 | 0.9835E 00 | -0.1230E 01 |
| 8 | 0.0 | 0.0 | 0.2158E 06 | -0.3619E 01 |
| 9 | 0.0 | 0.0 | 0.6610E 02 | -0.1038E 03 |
| 10 | 0.1352E 05 | 0.0 | 0.4425E 00 | -0.1351E 05 |
| 11 | 0.1791E 05 | 0.0 | 0.7837E 02 | -0.1787E 05 |
| 7 | 0.0 | 0.0 | 0.6137E 04 | -0.1057E 06 |

MONTH INDEX= 6 MONTH OF YEAR= 6

| QVHT | QVCL | QAHT | QACL | DD |
|---|---|---|---|---|
| 0.0 | -0.7295E 04 | 0.1061E 06 | -0.5304E 04 | 0.4122E 04 |

| I | SQSRC1 | SQSRC2 | SQCON1 | SQCON2 |
|---|---|---|---|---|
| 1 | 0.9784E 05 | 0.0 | 0.2546E 01 | -0.9784E 05 |
| 2 | 0.0 | 0.0 | 0.2986E 05 | -0.2963E 05 |
| 3 | 0.0 | 0.0 | 0.1345E 05 | -0.1332E 05 |
| 4 | 0.0 | 0.0 | 0.7381E 04 | -0.7276E 04 |
| 5 | 0.0 | 0.0 | 0.4959E 04 | -0.4848E 04 |
| 6 | 0.0 | 0.0 | 0.1121E 01 | -0.1230E 01 |
| 8 | 0.0 | 0.0 | 0.2274E 06 | -0.3391E 03 |
| 9 | 0.0 | 0.0 | 0.7673E 02 | -0.1092E 03 |
| 10 | 0.1563E 05 | 0.0 | 0.8095E 00 | -0.1560E 05 |
| 11 | 0.2084E 05 | 0.0 | 0.1283E 03 | -0.2080E 05 |
| 7 | 0.0 | 0.0 | 0.1282E 05 | -0.1063E 06 |

MONTH INDEX= 7 MONTH OF YEAR=

| QVHT | QVCL | QAHT | QACL | DD |
|---|---|---|---|---|
| 0.0 | -0.1114E 05 | 0.1062E 06 | -0.1232E 05 | 0.4128E 04 |

| I | SQSRC1 | SQSRC2 | SQCON1 | SQCON2 |
|---|---|---|---|---|
| 1 | 0.1131E 06 | 0.0 | 0.2893E 01 | -0.1130E 06 |
| 2 | 0.0 | 0.0 | 0.3345E 05 | -0.3328E 05 |
| 3 | 0.0 | 0.0 | 0.1509E 05 | -0.1499E 05 |
| 4 | 0.0 | 0.0 | 0.8344E 04 | -0.8256E 04 |
| 5 | 0.0 | 0.0 | 0.5691E 04 | -0.5600E 04 |
| 6 | 0.0 | 0.0 | 0.1279E 01 | -0.1231E 01 |
| 8 | 0.0 | 0.0 | 0.2382E 06 | -0.5953E 03 |
| 9 | 0.0 | 0.0 | 0.8195E 02 | -0.1140E 03 |
| 10 | 0.1817E 05 | 0.0 | 0.1352E 01 | -0.1813E 05 |
| 11 | 0.2439E 05 | 0.0 | 0.1480E 03 | -0.2434E 05 |
| 7 | 0.0 | 0.0 | 0.2370E 05 | -0.1064E 06 |

MONTH INDEX= 8 MONTH OF YEAR= 8

| QVHT | QVCL | QAHT | QACL | DD |
|---|---|---|---|---|
| 0.0 | -0.1522E 05 | 0.1065E 06 | -0.2061E 05 | 0.4150E 04 |

| I | SQSRC1 | SQSRC2 | SQCON1 | SQCON2 |
|---|---|---|---|---|
| 1 | 0.1289E 06 | 0.0 | 0.3902E 01 | -0.1287E 06 |
| 2 | 0.0 | 0.0 | 0.3729E 05 | -0.3713E 05 |
| 3 | 0.0 | 0.0 | 0.1684E 05 | -0.1673E 05 |
| 4 | 0.0 | 0.0 | 0.9344E 04 | -0.9246E 04 |
| 5 | 0.0 | 0.0 | 0.6428E 04 | -0.6338E 04 |
| 6 | 0.0 | 0.0 | 0.1436E 01 | -0.1231E 01 |
| 8 | 0.0 | 0.0 | 0.2486E 06 | -0.1278E 04 |
| 9 | 0.0 | 0.0 | 0.9145E 02 | -0.1191E 03 |
| 10 | 0.2079E 05 | 0.0 | 0.1761E 01 | -0.2072E 05 |
| 11 | 0.2800E 05 | 0.0 | 0.1902E 03 | -0.2794E 05 |
| 7 | 0.0 | 0.0 | 0.3610E 05 | -0.1067E 06 |

MONTH INDEX= 9 MONTH OF YEAR= 9

| QVHT | QVCL | QAHT | QACL | DD |
|---|---|---|---|---|
| 0.0 | -0.1894E 05 | 0.1078E 06 | -0.2352E 05 | 0.4225E 04 |

| I | SQSRC1 | SQSRC2 | SQCON1 | SQCON2 |
|---|---|---|---|---|
| 1 | 0.1441E 06 | 0.0 | 0.4303E 01 | -0.1436E 06 |
| 2 | 0.0 | 0.0 | 0.4150E 05 | -0.4139E 05 |
| 3 | 0.0 | 0.0 | 0.1878E 05 | -0.1868E 05 |
| 4 | 0.0 | 0.0 | 0.1054E 05 | -0.1045E 05 |
| 5 | 0.0 | 0.0 | 0.7377E 04 | -0.7308E 04 |

| | | | | |
|---|---|---|---|---|
| 6 | 0.0 | 0.0 | 0.1573E 01 | -0.1232E 01 |
| 8 | 0.0 | 0.0 | 0.2638E 06 | -0.1283E 04 |
| 9 | 0.0 | 0.0 | 0.1044E 03 | -0.1264E 03 |
| 10 | 0.2326E 05 | 0.0 | 0.1997E 01 | -0.2314E 05 |
| 11 | 0.3131E 05 | 0.0 | 0.2366E 03 | -0.3111E 05 |
| 7 | 0.0 | 0.0 | 0.4277E 05 | -0.1080E 06 |

MONTH INDEX= 10 MONTH OF YEAR= 10

| QVHT | QVCL | QAHT | QACL | DD |
|---|---|---|---|---|
| 0.0 | -0.2155E 05 | 0.1177E 06 | -0.2537E 05 | 0.4618E 04 |

| I | SQSRC1 | SQSRC2 | SQCON1 | SQCON2 |
|---|---|---|---|---|
| 1 | 0.1602E 06 | 0.0 | 0.4519E 01 | -0.1595E 06 |
| 2 | 0.0 | 0.0 | 0.4633E 05 | -0.4632E 05 |
| 3 | 0.0 | 0.0 | 0.2095E 05 | -0.2091E 05 |
| 4 | 0.0 | 0.0 | 0.1176E 05 | -0.1173E 05 |
| 5 | 0.0 | 0.0 | 0.8225E 04 | -0.8212E 04 |
| 6 | 0.0 | 0.0 | 0.1705E 01 | -0.1232E 01 |
| 8 | 0.0 | 0.0 | 0.2912E 06 | -0.1283E 04 |
| 9 | 0.0 | 0.0 | 0.1230E 03 | -0.1357E 03 |
| 10 | 0.2579E 05 | 0.0 | 0.2557E 01 | -0.2555E 05 |
| 11 | 0.3460E 05 | 0.0 | 0.2443E 03 | -0.3433E 05 |
| 7 | 0.0 | 0.0 | 0.4726E 05 | -0.1180E 06 |

MONTH INDEX= 11 MONTH OF YEAR= 11

| QVHT | QVCL | QAHT | QACL | DD |
|---|---|---|---|---|
| 0.0 | -0.2203E 05 | 0.1397E 06 | -0.2537E 05 | 0.5340E 04 |

| I | SQSRC1 | SQSRC2 | SQCON1 | SQCON2 |
|---|---|---|---|---|
| 1 | 0.1692E 06 | 0.0 | 0.4764E 01 | -0.1686E 06 |
| 2 | 0.0 | 0.0 | 0.4979E 05 | -0.4993E 05 |
| 3 | 0.0 | 0.0 | 0.2240E 05 | -0.2251E 05 |
| 4 | 0.0 | 0.0 | 0.1249E 05 | -0.1258E 05 |
| 5 | 0.0 | 0.0 | 0.8677E 04 | -0.8747E 04 |
| 6 | 0.0 | 0.0 | 0.1825E 01 | -0.1233E 01 |
| 8 | 0.0 | 0.0 | 0.3254E 06 | -0.1283E 04 |
| 9 | 0.0 | 0.0 | 0.1363E 03 | -0.1406E 03 |
| 10 | 0.2717E 05 | 0.0 | 0.2620E 01 | -0.2703E 05 |
| 11 | 0.3637E 05 | 0.0 | 0.2485E 03 | -0.3608E 05 |
| 7 | 0.0 | 0.0 | 0.4775E 05 | -0.1400E 06 |

MONTH INDEX= 12    MONTH OF YEAR= 12

| QVHT | QVCL | QAHT | QACL | DD |
|---|---|---|---|---|
| 0.0 | -0.2203E 05 | 0.1770E 06 | -0.2537E 05 | 0.6486E 04 |

| I | SQSRC1 | SQSRC2 | SQCON1 | SQCON2 |
|---|---|---|---|---|
| 1 | 0.1777E 06 | 0.0 | 0.4930E 01 | -0.1771E 06 |
| 2 | 0.0 | 0.0 | 0.5346E 05 | -0.5360E 05 |
| 3 | 0.0 | 0.0 | 0.2395E 05 | -0.2405E 05 |
| 4 | 0.0 | 0.0 | 0.1325E 05 | -0.1331E 05 |
| 5 | 0.0 | 0.0 | 0.9116E 04 | -0.9169E 04 |
| 6 | 0.0 | 0.0 | 0.1948E 01 | -0.1233E 01 |
| 8 | 0.0 | 0.0 | 0.3741E 06 | -0.1283E 04 |
| 9 | 0.0 | 0.0 | 0.1446E 03 | -0.1424E 03 |
| 10 | 0.2844E 05 | 0.0 | 0.2626E 01 | -0.2831E 05 |
| 11 | 0.3800E 05 | 0.0 | 0.2486E 03 | -0.3772E 05 |
| 7 | 0.0 | 0.0 | 0.4775E 05 | -0.1773E 06 |

SUMMARY -- MTIME= 8784    NSTEP= 9636    NCALC=16835    KERR= 0    KINC= 0

| MO | DEG DAY | QOUT | QHEAT | QCOOL | QSOLAR | QLOAD | QACL | QSINC | SCL/USED | PCTSCL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1360. | 13097. | 39380. | -91. | 14695. | 41419. | 0. | 24119. | 2038. | 4.92 |
| 2 | 1182. | 13245. | 31367. | -760. | 20063. | 37381. | 0. | 33208. | 6014. | 16.09 |
| 3 | 827. | 9989. | 20820. | -1622. | 19153. | 27910. | 0. | 33630. | 7090. | 25.40 |
| 4 | 429. | 6545. | 8623. | -2366. | 17286. | 16797. | -44. | 32126. | 6174. | 48.66 |
| 5 | 287. | 5202. | 5383. | -1105. | 13958. | 12904. | -273. | 26666. | 7521. | 58.29 |
| 6 | 38. | 1460. | 573. | -6675. | 12683. | 5731. | -4988. | 24646. | 5158. | 90.00 |
| 7 | 7. | 658. | 90. | -10857. | 15279. | 4740. | -7015. | 29826. | 4651. | 96.11 |
| 8 | 22. | 257. | 262. | -12380. | 15790. | 4661. | -8296. | 29899. | 4399. | 94.38 |
| 9 | 75. | 2429. | 1302. | -5622. | 15176. | 7407. | -2908. | 26789. | 6105. | 82.42 |
| 10 | 393. | 5649. | 9950. | -4461. | 16076. | 16131. | -1849. | 26976. | 6181. | 38.32 |
| 11 | 722. | 7457. | 21961. | -483. | 9084. | 23646. | 0. | 14961. | 1685. | 7.13 |
| 12 | 1146. | 10273. | 37310. | 0. | 8438. | 35508. | 0. | 13905. | -1803. | -5.08 |
| SUMS | 6486. | 76261. | 177020. | -47402. | 177679. | 234234. | -25372. | 316752. | 57214. | 19 |
| SUMS | 24. | | | | | | | | | |

TOTALS    QVHT    QVCL    QAHT    QACL    DD    QHSUM

0.0 -0.2203E 05 0.1770E 06 -0.2537E 05 0.6486E (

| I | SQSRC1 | SQSRC2 | SQCON1 | SQCON2 |
|---|---|---|---|---|
| 1 | 0.1777E 06 | 0.0 | 0.4930E 01 | -0.1771E 06 |
| 2 | 0.0 | 0.0 | 0.5346E 05 | -0.5360E 05 |
| 3 | 0.0 | 0.0 | 0.2395E 05 | -0.2405E 05 |
| 4 | 0.0 | 0.0 | 0.1325E 05 | -0.1331E 05 |
| 5 | 0.0 | 0.0 | 0.9116E 04 | -0.9169E 04 |
| 6 | 0.0 | 0.0 | 0.1948E 01 | -0.1233E 01 |
| 8 | 0.0 | 0.0 | 0.3741E 06 | -0.1283E 04 |
| 9 | 0.0 | 0.0 | 0.1446E 03 | -0.1424E 03 |
| 10 | 0.2844E 05 | 0.0 | 0.2626E 01 | -0.2831E 05 |
| 11 | 0.3800E 05 | 0.0 | 0.2486E 03 | -0.3772E 05 |
| 7 | 0.0 | 0.0 | 0.4775E 05 | -0.1773E 06 |

| J | I1 | I2 | SQC121 | SQC122 |
|---|---|---|---|---|
| 1 | 1 | 10 | 0.6344E 05 | 0.0 |
| 2 | 1 | 2 | 0.7969E 05 | -0.7102E 05 |
| 3 | 2 | 3 | 0.3895E 05 | -0.3013E 05 |
| 4 | 3 | 4 | 0.2205E 05 | -0.1313E 05 |
| 5 | 4 | 5 | 0.1816E 05 | -0.9179E 04 |
| 6 | 5 | 6 | 0.2129E 05 | -0.1225E 05 |
| 7 | 6 | 7 | 0.2129E 05 | -0.1225E 05 |
| 8 | 7 | 8 | 0.2341E 06 | -0.3331E 04 |
| 9 | 9 | 7 | 0.9222E 05 | -0.1324E 02 |
| 10 | 1 | 9 | 0.1050E 06 | 0.0 |
| 11 | 9 | 10 | 0.2903E 05 | -0.1622E 05 |
| 12 | 10 | 11 | 0.1053E 06 | -0.8479E 03 |
| 13 | 11 | 8 | 0.1420E 06 | -0.1389E 03 |

CANADIAN WEATHER READING PROGRAM FROM ENCORE CANADA.

FILE N$^{\underline{o}}$ 2 on TAPE TA 1219

DSN = PASDAT2.

```
C THIS PROGRAM IS THE WEATHER PROGRAM FROM PORTIONS OF ENCORE
C CANADA. IT TRANSFORMS DATA INTO FORMAT ACCEPTABLE TO PASOLE
C UNITS ARE ENGLISH.
C*************************************************************
      DIMENSION HANGLE(24),IDIR(24),IDIF(24)
      DIMENSION  DIR(50),DIF(50),X(366),Y(366),Z(366),TOF(24)
      DIMENSION NAME( 3),DEABC( 5),DNR(24),RAD(24),PRC(24),
     1 BSKY(24),IDBT(24),ICLC(24),IVEL(24),WDIR(24),PATMOS(24)
      INTEGER TDB(24),WVEL(24),SRAD(24)
      DATA I3/2/
C READ IN YEARLY DATA FRO WEATHER FILE
      READ(I3) IYEAR,LEAP,NOCITY,NAME,IPROV,DNLAT,DWLON,
     1 ITZN,ITZ,SSCN,WSCN,RADLON,SINLAT,COSLAT,TANLAT
      NDAYS=365
      IF(LEAP.EQ.1) NDAYS=366
      CALL SOLRAD (NWALL,NROOM,IWA,IWB,WAZIM,WTILT,NORAD,AZIM,
     1 TILT,NRAD)
C INITIALIZE EVERYTHING ZERO
      YTDIR=0.
      YTDIF=0.
      KDAYS=0
       DO 87 IDAY=1,NDAYS
C READ DAILY DATA
       READ(I3) IDOY,ID,MONTH,IDWEEK,NAMDAY,IWH,SUNRAS,DEABC,
     1 CN,ROGDAY
C READ DAILY DATA
       READ(I3) IDBT,ICLC,IVEL,WDIR,PATMOS,HANGLE,BSKY,DNR,PRC
       KDAYS=KDAYS+1
C
C CONSIDER 24 HOURS OF ANY DAY
C
      DO 65 IHOUR=1,24
      IHRM1=IHOUR-1
      IF(IHRM1.EQ.0) IHRM1=24
C
       IF(ICLOUD.GT.0) ICLC(IHOUR)=ICLOUD
   16 IDACLC=IDACLC+ICLC(IHOUR)
       CALL DIRDIF(DEABC,COSLAT,SINLAT,HANGLE,SUNRAS,PRC,DNR,
     1 BSKY,ROGDAY,NORAD,AZIM,TILT,IHOUR,IHRM1,CE,DIR,DIF)
C CONVERT DRY BULB TEMP INTO DEGREE F  FROM DEG. C
      TOF(IHOUR)=1.8*IDBT(IHOUR)+32
      DATOF=DATOF+TOF(IHOUR)
C CONVERT WIND SPEED AT SITE TO MPH
      W=0.6213722*IVEL(IHOUR)
      IDIR(IHOUR)=DIR(NORAD)
      IDIF(IHOUR)=DIF(NORAD)
       WVEL(IHOUR)=W
      TDB(IHOUR)= TOF(IHOUR)
   65 CONTINUE
       IIYEAR=  MOD(IYEAR,100)
      INDATE=MONTH*10000+ID*100+IIYEAR
      WRITE(6,44) INDATE,TDB
      WRITE(6,44) INDATE,WVEL
      WRITE(6,44) INDATE,IDIR
      WRITE(6,44) INDATE,IDIF
```

```
      WRITE(13,44) INDATE,TDB
      WRITE(13,44) INDATE,WVEL
      WRITE(13,44) INDATE,IDIR
      WRITE(13,44) INDATE,IDIF
   44 FORMAT(1X,I6,24I3)
   87 CONTINUE
      ENDFILE 13
      REWIND 13
      STOP
      END
C ****************************************************************
C SUBROUTINE SOLRAD IT SETS OUT THE HORIZONTAL SURFACE FOR SOLAR
C RADIATION CALCULATION.
C
       SUBROUTINE  SOLRAD (NWALL,NROOM,IWA,IWB,WAZIM,WTILT,NORAD,AZIM,
     1  TILT,NRAD)
       NORAD=1
       NWALL=1
       NROOM=1
       IWA=1
       IWB=2
       WAZIM=180.
       WTILT=0.00
       AZIM=0.00
       TILT=0.00
       NRAD=1
       RETURN
       END
C ****************************************************************
C SUROUTINE DIRDIF  COMPUTES DIRECT AND DIFFUSE RADIATION ON AN
C ARBITRARILY ORIENTED SURFACE HERE HORIZONTAL
       SUBROUTINE DIRDIF(DEABC,CL,SL,HANGLE,SUNRAS,PRC,DNR,BSKY,
     1 ROGDAY,NORAD,A,T,I,M,CE,DIR,DIF)
C**********
      DIMENSION HANGLE(24)
      DIMENSION  DIR(50),DIF(50),X(366),Y(366),Z(366),TOF(24)
      DIMENSION NAME( 3),DEABC( 5),DNR(24),RAD(24),PRC(24),
     1 BSKY(24),IDBT(24),ICLC(24),IVEL(24),WDIR(24),PATMOS(24)
      INTEGER TDB(24),WVEL(24),SRAD(24)
       DIMENSION A(NORAD),T(NORAD),CE(NORAD)
C*****************
C IS SUN UP
C*************
       H=HANGLE(I)
       IF(ABS(H).GT.ABS(SUNRAS)) GO TO 4
C
C  SUN IS UP
C
       CH=COS(H)
       SH=SIN(H)
       CD=1/SQRT(DEABC(1)**2+1)
       SD=CD*DEABC(1)
       SDCL=SD*CL
       CDSL=CD*SL
       SDSL=SD*SL
```

```
      CDCL=CD*CL
      CDSH=CD*SH
      RC=SDSL+CDCL*CH
      CS=SDCL-CDSL*CH
C
C   FIND CORRECTION FACTOR
C
      PC=50/(100-PRC(I))
C CONVERT W/M**2 TO BTU/HR FT**2 AND APPLY CORRECTION FACTOR
C
      DN=0.316997*PC*(DNR(I)+DNR(M))
      BS=0.316997*PC*(BSKY(I)+BSKY(M))
      BG=ROGDAY*(BS+DN*RC)
C
      CT=COS(T)
      ST=SIN(T)
      CE(NORAD)=CT*RC-ST*COS(A(NORAD))*CS-ST*SIN(A(NORAD))*CDSH
      DIR(NORAD)=0.0
      IF(CE(NORAD).GT.0.0) DIR(NORAD)=DN*CE(NORAD)
C CHECK SURFACE IS ORIENTED TOWARDS SKY
C
      IF(CT.LT.+0.7071067)  GO TO 1
C SURFACE IS ORIENTED TOWARDS SKY
C
       DIF(NORAD)=BS
       GO TO 3
  1   IF(CT.GT.-0.7071067)  GO TO 2
       DIF(NORAD)=BG
       GO TO 3
C THE SURFACE TILT IS BETWEEN 45 AND 135
C
  2   Y(NORAD)=0.45
      IF(CE(NORAD).GE.-0.2)  Y(NORAD)=0.55+(0.437+0.313*CE(NORAD))
   1  *CE(NORAD)
      DIF(NORAD)=Y(NORAD)*BS+BG*(1-CT)/2
  3   CONTINUE
      RETURN
C
C SUN IS DOWN
C
  4   CE(NORAD)=0.0
      DIR(NORAD)=0.0
  5   DIF(NORAD)=0.0
      RETURN
      END
```

U.S.A. WEATHER READING PROGRAM.FROM ESP.
FILE N° 1 on TAPE TA 1219.
DSN = PASDAT1.

```
C THIS PROGRAM IS THE WEATHER PROGRAM FROM ESP .  IT CONVERTS WEATHER
C WEATHER DATA TO FORMAT ACCEPTABLE TO PASOLE. THE WEATHER IS IN
C ENGLISH UNITS. THE MUST BE SUPPLIED ON TAPE OR ON DISK.
C
C   ****************************************************************
C   *                                                              *
C   *    AUTOMATED PROCEDURES FOR ENGINEERING CONSULTANTS, INC.    *
C   *                                                              *
C   *              ENERGY SIMULATION PROGRAM  -  ESP-1             *
C   *                                                              *
C   *    CDC-VERSION  DEVELOPED  BY - FERREIRA ASSOCIATES, INC.    *
C   *                                                              *
C   *                                                              *
C   *                        WEATHER PROGRAM                       *
C   *                                                              *
C   *                                                              *
C   *                        WEATHR  VER 01 LEV 04 12/ 1/79        *
C   *                                                              *
C   ****************************************************************
C
C   INPUT FILE   5 - INPUT CARDS
C   OUTPUT FILE  6 - PRINTED OUTPUT
C
C   INPUT TAPE  12 - TEST REFERENCE YEAR (TRY) WEATHER TAPE
C                    SOURCE- NATIONAL CLIMATIC CENTER
C   OUTPUT FILE 13 - SITE WEATHER FILE
C                    DESTINATION- ESP-1 LOADS PROGRAM
C
C
      COMMON /INPOUT/
     1   IREAD,IPRNT,ITRY,ISWF,IERR,TITLEA(10),TITLEB(10),
     2   TITLEC(10),APEC(14),ESP(8),NMON,NDAY,NYEAR,NPAGE
      COMMON /WTHPRM/
     1   PC1,PC2,PC3,PBSTAT,PBSITE,RPB,FA(6),FB(6),FC(6),
     2   CPMON(12),CQMON(12),CRMON(12),CP,CQ,CR,
     3   BND1(14),BND2(14),DPARM(14),DIG(14),ITOPT(14),NMISS(14),
     4   ISW(48,14),TOA(48),TWB(48),PATM(48),
     5   WDIRD(48),WVELK(48),TCA(48),CA(48,4),TOC(48,4),
     6   TDP(25),WOA(25),HOA(25),DOA(25),WDIRR(25),WVELM(25),FO(6,25)
C CDC VERSION - BEGIN
C     CALL REMARK('  ESP-I  VERSION 1,  LEVEL 4.0')
C     CALL REMARK('  CDC  VERSION  -  WEATHER ')
C     CALL REMARK('  MAINTAIN BY FERREIRA ASSOC.')
C CDC VERSION - END
C
C   READ USER INPUT CARDS - TERMINATE IF THERE ARE ERRORS
C
      CALL INCAR
      IF (IERR.NE.0) GO TO 110
C
C   CHECK INPUT WEATHER TAPE AND INITIALIZE FOR PROCESSING
C
      CALL INIT
      IF (IERR.NE.0) GO TO 110
C
```

```
C   PROCESS WEATHER DATA ONE DAY AT A TIME
C
      CALL DAYLUP
C
C   CLOSE FILES
C
      REWIND ITRY
      ENDFILE ISWF
      REWIND ISWF
C
C   PRINT INTERPOLATION SUMMARY REPORT
C
      NMT = 0
      DO 100 I = 1,14
      NMT = NMT + NMISS(I)
  100 CONTINUE
      NPAGE = NPAGE + 1
      WRITE(IPRNT,1000) APEC,NMON,NDAY,NYEAR,ESP,NPAGE
      WRITE(IPRNT,1010) (NMISS(J),J=1,6),    (NMISS(J),NMISS(J+4),J=7,10)
     1       ,NMT
C
C   TERMINATE
C
  110 CONTINUE
      CALL EXIT
      STOP
C
C
 1000 FORMAT(1H1,14A4,10X,I2,1H/,I2,1H/,I2/1X,74(1H-)/
     2    1X,8A4,34X,4HPAGE,1X,I3/1X,74(1H*)/)
 1010 FORMAT(/////27X,'INTERPOLATION SUMMARY'/////
     2    26X,'NUMBER OF HOURS'/
     3    6X,'PARAMETER',11X,'DATA WAS MISSING'///
     4    1X,'DRY BULB TEMPERATURE',11X,I4/
     5    1X,'WET BULB TEMPERATURE',11X,I4/
     6    1X,'BAROMETRIC PRESSURE',12X,I4/
     7    1X,'WIND DIRECTION',17X,I4/
     8    1X,'WIND SPEED',21X,I4/
     9    1X,'TOTAL CLOUD AMOUNT',13X,I4/
     A    1X,'FIRST CLOUD LAYER'/
     B    6X,'AMOUNT',20X,I4/6X,'TYPE',22X,I4/
     C    1X,'SECOND CLOUD LAYER'/
     D    6X,'AMOUNT',20X,I4/6X,'TYPE',22X,I4/
     E    1X,'THIRD CLOUD LAYER'/
     F    6X,'AMOUNT',20X,I4/6X,'TYPE',22X,I4/
     G    1X,'FOURTH CLOUD LAYER'/
     H    6X,'AMOUNT',20X,I4/6X,'TYPE',22X,I4/
     I    32X,'----'///1X,'TOTAL MISSING DATA ITEMS',5X,I6)
      END
      BLOCK DATA
C
      COMMON /INPOUT/
     1    IREAD,IPRNT,ITRY,ISWF,IERR,TITLEA(10),TITLEB(10),
     2    TITLEC(10),APEC(14),ESP(8),NMON,NDAY,NYEAR,NPAGE
C
```

```
      COMMON /HDRPRM/
     1  NSTAT,NSITE,JYEAR,LEAP,ELSTAT,SLAT,SLON,ELSITE,
     2  NTZ,CNS,CNW,STAID(6),SITID(6)
C
      COMMON /DAILYP/
     1  KDST,JDSTM(12),NSCH,ISCH,NEXT,NDPP,LDPP,LPR(25),LPOPTC,
     2  LMBEG(20),LDBEG(20),LMEND(20),LDEND(20),
     3  LPOPT(20),LPRSW(25,20),LBEG(20),LEND(20),
     4  NDOY,JDOY,JMON,JDOM,JDOW,JDST,JHOL,KMON,KDOM
C
      COMMON /WTHPRM/
     1  PC1,PC2,PC3,PBSTAT,PBSITE,RPB,FA(6),FB(6),FC(6),
     2  CPMON(12),CQMON(12),CRMON(12),CP,CQ,CR,
     3  BND1(14),BND2(14),DPARM(14),DIG(14),ITOPT(14),NMISS(14),
     4  ISW(48,14),TOA(48),TWB(48),PATM(48),
     5  WDIRD(48),WVELK(48),TCA(48),CA(48,4),TOC(48,4),
     6  TDP(25),WOA(25),HOA(25),DOA(25),WDIRR(25),WVELM(25),FO(6,25)
C
      COMMON /SOLRAD/
     1  A0(9),A1(9),A2(9),A3(9),B1(9),B2(9),B3(9),
     2  TSD,SET,SA,SB,SC,TZN12,CNMON(12),CN,CN2I,
     3  SLATR,SSLAT,CSLAT,TSLAT,SLONR,
     4  ISUN(25),COSW(25),COSS(25),COSZ(25),
     5  CC(25),CCF(25),RDRHC(25),RDFHC(25),FDIFF(25)
      DATA A0/-.00527,0.696E-4,368.44,0.,0.,
     2          .1717,.0905,.1717,.0905/,
     3  A1/-.4001,.00706,24.52,0.,0.,
     4          -.0344,-.0410,.0344,.0410/,
     5  A2/-.003996,-.0533,-1.14,0.,0.,
     6          .0032,.0073,.0032,.0073/,
     7  A3/-.00424,-.00157,-1.09,0.,0.,
     8          .0024,.0015,-.0024,-.0015/
      DATA B1/.0672,-.122,.58,0.,0.,
     2          -.0043,-.0034,.0043,.0034/,
     3  B2/0.,-.156,-.18,0.,0.,
     4          0.,.0004,0.,.0004/,
     5  B3/0.,-.00556,.28,0.,0.,
     6          -.0008,-.0006,.0008,.0006/
      DATA TSD/0./,SET/0./,SA/0./,SB/0./,SC/0./,TZN12/0./,
     2  CNMON/12*0./,CN/0./,CN2I/0./,
     3  SLATR/0./,SSLAT/0./,CSLAT/0./,TSLAT/0./,SLONR/0./,
     4  ISUN/25*0/,COSW/25*0./,COSS/25*0./,COSZ/25*0./,
     5  CC/25*0./,CCF/25*0./,
     6  RDRHC/25*0./,RDFHC/25*0./,FDIFF/25*0./
C
      DATA IREAD/5/,IPRNT/6/,ITRY/12/,ISWF/13/,IERR/0/,
     2  CNMON/12*0./,CN/0./,CN2I/0./,
     3  SLATR/0./,SSLAT/0./,CSLAT/0./,TSLAT/0./,SLONR/0./,
     4  ISUN/25*0/,COSW/25*0./,COSS/25*0./,COSZ/25*0./,
     5  ESP /'ESP-','1 WE','ATHR','    ',
     6       '   V','ER 0','1 LE','V 04'/,
     7  NMON/0/,NDAY/0/,NYEAR/0/,NPAGE/0/
      DATA NSTAT/0/,NSITE/0/,JYEAR/0/,LEAP/0/,ELSTAT/0./,
     2  SLAT/0./,SLON/0./,ELSITE/0./,NTZ/0/,CNS/0./,
     3  CNW/0./,STAID/6*'    '/,SITID/6*'    '/
```

```
      DATA KDST/0/,JDSTM/12*0/,NSCH/0/,ISCH/0/,NEXT/0/,NDPP/0/,LDPP/0/,
     2 LPR/25*0/,LPOPTC/0/,LMBEG/20*0/,LDBEG/20*0/,LMEND/20*0/,
     3 LDEND/20*0/,LPOPT/20*0/,LPRSW/500*0/,
     4 LBEG/20*0/,LEND/20*0/,NDOY/0/,JDOY/0/,JMON/0/,
     5 JDOM/0/,JDOW/0/,JDST/0/,JHOL/0/,KMON/0/,KDOM/0/
      DATA PC1/1.36264E-8/,PC2/-1.07176E-3/,PC3/29.92/,
     2 PBSTAT/0./,PBSITE/0./,RPB/0./,
     3 FA/0.0  ,0.001,0.0  ,-0.002,0.0  ,-0.00125/,
     4 FB/0.464,0.320,0.330,0.315 ,0.244,0.262   /,
     5 FC/2.04 ,2.20 ,1.90 ,1.45  ,1.80 ,1.45    /,
     6 CPMON/2*1.14  ,3*1.06   ,3*0.96   ,3*0.95   ,1.14  /,
     7 CQMON/2*0.003  ,3*0.012  ,3*0.033  ,3*0.030  ,0.003 /,
     8 CRMON/2*-0.0082,3*-0.0084,3*-0.0106,3*-0.0108,-0.0082/,
     9 CP/0./,CQ/0./,CR/0./
      DATA BND1/-80.,-80.,19.00,   0.,   0.,0.0,4*0.0,4*0./,
     2 BND2  /140.,140.,39.99,360.,230.,10.,4*10.,4*9./,
     3 DPARM / 50., 42.,29.92,   0.,   0.,0.0,4*0.0,4*0./,
     4 DIG   /  1.,  1.,  100.,   1.,   1.,1.0,4*1.0,4*1./,
     5 ITOPT /  3 ,  3 ,   3 ,  2 ,  3 , 3 ,4*3  ,4*2 /,
     6 NMISS/14*0/,ISW/672*0/,TOA/48*0./,TWB/48*0./,PATM/48*0./,
     7 WDIRD/48*0./,WVELK/48*0./,TCA/48*0./,
     8 CA/192*0./,TOC/192*0./,TDP/25*0./,WOA/25*0./,HOA/25*0./,
     9 DOA/25*0./,WDIRR/25*0./,WVELM/25*0./,FO/150*0./
      END
      SUBROUTINE DAYLUP
C
C     A SUBROUTINE WHICH CONTROLS THE DAY BY DAY
C     PROCESSING OF WEATHER DATA.
C
      DIMENSION PRM(48,14)
      COMMON /INPOUT/
     1 IREAD,IPRNT,ITRY,ISWF,IERR,TITLEA(10),TITLEB(10),
     2 TITLEC(10),APEC(14),ESP(8),NMON,NDAY,NYEAR,NPAGE
      COMMON /DAILYP/
     1 KDST,JDSTM(12),NSCH,ISCH,NEXT,NDPP,LDPP,LPR(25),LPOPTC,
     2 LMBEG(20),LDBEG(20),LMEND(20),LDEND(20),
     3 LPOPT(20),LPRSW(25,20),LBEG(20),LEND(20),
     4 NDOY,JDOY,JMON,JDOM,JDOW,JDST,JHOL,KMON,KDOM
      COMMON /WTHPRM/
     1 PC1,PC2,PC3,PBSTAT,PBSITE,RPB,FA(6),FB(6),FC(6),
     2 CPMON(12),CQMON(12),CRMON(12),CP,CQ,CR,
     3 BND1(14),BND2(14),DPARM(14),DIG(14),ITOPT(14),NMISS(14),
     4 ISW(48,14),TOA(48),TWB(48),PATM(48),
     5 WDIRD(48),WVELK(48),TCA(48),CA(48,4),TOC(48,4),
     6 TDP(25),WOA(25),HOA(25),DOA(25),WDIRR(25),WVELM(25),FO(6,25)
      COMMON /SOLRAD/
     1 A0(9),A1(9),A2(9),A3(9),B1(9),B2(9),B3(9),
     2 TSD,SET,SA,SB,SC,TZN12,CNMON(12),CN,CN2I,
     3 SLATR,SSLAT,CSLAT,TSLAT,SLONR,
     4 ISUN(25),COSW(25),COSS(25),COSZ(25),
     5 CC(25),CCF(25),RDRHC(25),RDFHC(25),FDIFF(25)
C
      EQUIVALENCE(PRM(1,1),TOA(1))
C
      DATA DUM/0./,IDUM1/0/,IDUM2/0/
```

```
C
      DO 310 JDOY = 1,NDOY
C
C     MOVE CURRENT DAY'S DATA INTO PLACE
C
      JMON = KMON
      JDOM = KDOM
         DO 110 IHOD = 1,24
         KHOD = IHOD + 24
            DO 100 JP = 1,14
            PRM(IHOD,JP) = PRM(KHOD,JP)
            ISW(IHOD,JP) = ISW(KHOD,JP)
            ISW(KHOD,JP) = 0
 100        CONTINUE
 110     CONTINUE
C
C     CHECK FOR LAST DAY OF YEAR
C
      IF (JDOY.NE.NDOY) GO TO 130
C
C     LAST DAY OF YEAR - INITIALIZE DATA FOR LAST HOUR
C
      IT = 4
         DO 120 JP = 1,14
         CALL VALCHK(IT,PRM(1,JP),BND1(JP),BND2(JP),        DPARM(JP),
     1   DUM,IDUM1,IDUM2)
 120     CONTINUE
      GO TO 140
C
C     READ NEXT DAY'S DATA
C
 130  CONTINUE
C
      READ(ITRY,1000) (TOA(I),TWB(I),WDIRD(I),    WVELK(I),PATM(I),TCA(I)
     1      ,(CA(I,J),    TOC(I,J),J=1,4),KMON,KDOM,I=25,48)
C
C     DAY OF WEEK
C
 140  CONTINUE
      JDOW = JDOW + 1
      IF (JDOW.GT.7) JDOW = 1
C
C     DAYLIGHT SAVINGS TIME FLAG
C
      IF (KDST.NE.0) GO TO 150
      IF (JMON.EQ.4.AND.JDOM.GE.24.AND.JDOW.EQ.1) JDST = 1
      IF (JMON.EQ.10.AND.JDOM.GE.25.AND.JDOW.EQ.1) JDST = 0
C     CALCULATE HOLIDAY FLAG
C
 150  CONTINUE
      JHOL = 0
      GO TO (160,170,240,240,180,240,190,    240,200,210,220,230),JMON
 160  CONTINUE
      IF (JDOM.EQ.1 .OR. JDOM.EQ.2.AND.JDOW.EQ.2) JHOL = 1
      GO TO 240
```

```
170 CONTINUE
    IF (JDOM.GE.15.AND.JDOM.LE.21.AND.JDOW.EQ.2) JHOL = 1
    GO TO 240
180 CONTINUE
    IF (JDOM.GE.25.AND.JDOW.EQ.2) JHOL = 1
    GO TO 240
190 CONTINUE
    IF (JDOM.EQ.4 .OR. JDOM.EQ.3.AND.JDOW.EQ.6 .OR.
   1 JDOM.EQ.5.AND.JDOW.EQ.2) JHOL = 1
    GO TO 240
200 CONTINUE
    IF (JDOM.LE.7.AND.JDOW.EQ.2) JHOL = 1
    GO TO 240
210 CONTINUE
    IF (JDOM.GE.8.AND.JDOM.LE.14.AND.JDOW.EQ.2 .OR.
   1 JDOM.GE.22.AND.JDOM.LE.28.AND.JDOW.EQ.2)   JHOL = 1
    GO TO 240
220 CONTINUE
    IF (JDOM.GE.22.AND.JDOM.LE.28.AND.JDOW.EQ.5) JHOL = 1
    GO TO 240
230 CONTINUE
    IF (JDOM.EQ.25 .OR. JDOM.EQ.24.AND.JDOW.EQ.6 .OR.
   1 JDOM.EQ.26.AND.JDOW.EQ.2 .OR. JDOM.EQ.31.AND.JDOW.EQ.6) JHOL
   2 = 1
240 CONTINUE
C
C   CHANGE MONTHLY PARAMETERS IF FIRST DAY OF MONTH
C
    IF (JDOM.NE.1) GO TO 250
    IF (KDST.NE.0) JDST = JDSTM(JMON)
    CP = CPMON(JMON)
    CQ = CQMON(JMON)
    CR = CRMON(JMON)
    CN = CNMON(JMON)
    CN2I = 1. / (CN * CN)
C
C   DISTINGUISH BETWEEN CIRROSTRATUS AND UNKNOWN CLOUD TYPES
C
250 CONTINUE
    BD1 = BND1(7)
    BD2 = BND2(7)
    BD3 = BND2(11) + 1.
        DO 270 IHOD = 25,48
            DO 260 J = 1,4
            IF (CA(IHOD,J).LT.BD1.OR.          CA(IHOD,J).GT.BD2)
   1 TOC(IHOD,J) = BD3
260         CONTINUE
270     CONTINUE
C
C     CHECK VALIDITY OF WEATHER PARAMETERS
C
        DO 280 JP = 1,14
        CALL VALCHK(ITOPT(JP),PRM(1,JP),       BND1(JP),BND2(JP),DUM,
   1    DIG(JP),NMISS(JP),         ISW(1,JP))
280     CONTINUE
```

```
C
C   ENSURE CONSISTENCY OF CLOUD AMOUNTS
C
      DO 300 IHOD = 2,25
      TC = TCA(IHOD)
        DO 290 J = 1,4
        IF(CA(IHOD,J).GT.TC) CA(IHOD,J) = TC
        TC = TC - CA(IHOD,J)
 290    CONTINUE
 300  CONTINUE
C
C   CALCULATE PSYCHROMETRIC, WIND, AND FILM PARAMETERS.
C
      CALL WPSY
C   CALCULATE CLOUD AND SOLAR PARAMETERS
C
      CALL SOLAR
C
C   OUTPUT DAY RECORD TO SITE-WEATHER-FILE
C
      CALL OUTDAY
C
 310 CONTINUE
C
      RETURN
C
C
1000 FORMAT((5X,2F3.0,3X,2F3.0,F4.2,1X,F2.0,F2.0,F1.0,
    2   3X,3(F2.0,F1.0,5X),16X,2I2))
      END
        FUNCTION DPF (PV)
C
C   A SUBROUTINE WHICH CALCULATES
C              DEW POINT TEMPERATURE   DPF
C   WHEN GIVEN
C              VAPOR PRESSURE          PV
C
      Y=ALOG(PV)
      IF (PV.GT.0.1836) GO TO 100
      DPF=71.98+24.873*Y+0.8927*Y*Y
      GO TO 110
C
 100 DPF=79.047+30.579*Y+1.8893*Y*Y
C
 110 RETURN
      END
      SUBROUTINE INCAR
C
C   A SUBROUTINE WHICH READS USER INPUT CARDS,
C   CHECKS FOR ERRORS, AND PRINTS ERROR MESSAGES
C   WHERE APPROPRIATE.
C
      DIMENSION WCARD(6),CARDCK(6),
     2  YRLEAP(5,2),DSTKY(6,2),WOPT(3,2),
     3  NDM(12),NDBM(12)
```

```
      DIMENSION ESP1(96)
      COMMON /INPOUT/
     1   IREAD,IPRNT,ITRY,ISWF,IERR,TITLEA(10),TITLEB(10),
     2   TITLEC(10),APEC(14),ESP(8),NMON,NDAY,NYEAR,NPAGE
      COMMON /HDRPRM/
     1   NSTAT,NSITE,JYEAR,LEAP,ELSTAT,SLAT,SLON,ELSITE,
     2   NTZ,CNS,CNW,STAID(6),SITID(6)
      COMMON /DAILYP/
     1   KDST,JDSTM(12),NSCH,ISCH,NEXT,NDPP,LDPP,LPR(25),LPOPTC,
     2   LMBEG(20),LDBEG(20),LMEND(20),LDEND(20),
     3   LPOPT(20),LPRSW(25,20),LBEG(20),LEND(20),
     4   NDOY,JDOY,JMON,JDOM,JDOW,JDST,JHOL,KMON,KDOM
C
      DATA WCARD/6*'    '/,
     2   CARDCK/'WTA','WTB','WTC','WTD','WTE','WTF'/,
     3   YRLEAP/'(NOT',' A L','EAP ','YEAR',')   ',
     4          '(LEA','P YE','AR) ','    ','    '/,
     5   DSTKY/'AUTO','MATI','C   ','    ','    ','    ',
     6          'INPU','T  -','  JF','MAMJ','JASO','ND  '/,
     7   WOPT/'0 - ','MAJO','R   ','1 - ','ALL ','    '/,
     8   NDM/31,28,31,30,31,30,31,31,30,31,30,31/,
     9   NDBM/0,31,59,90,120,151,181,212,243,273,304,334/
C
      DATA ESP1/'EEEE','EEEE','    ','SSSS','SS  ',
     2   '  PP','PPPP','P   ','    ','    ','IIII','IIII',
     3   'EEEE','EEEE','   S','SSSS','SSS ','  PP','PPPP',
     4   'PP  ','    ','    ','IIII','IIII','EE  ','    ',
     5   '   S','S   ','    ','  PP','    ','PP  ','    ',
     6   '    ','   I','I   ','EEEE','EEE ','   S','SSSS',
     7   'SS  ','  PP','PPPP','PP  ',' ===','=   ','   I',
     8   'I   ','EEEE','EEE ','    ','SSSS','SSS ','  PP',
     9   'PPPP','P   ','    ','    ','   I','I   ','EE  ',
     A   '    ','    ','    ',' SS ','  PP','    ','    ',
     B   '    ','    ','   I','I   ','EEEE','EEEE','   S',
     C   'SSSS','SSS ','  PP','    ','    ','    ','    ',
     D   'IIII','IIII','EEEE','EEEE','    ','SSSS','SS  ',
     E   '  PP','    ','    ','    ','    ','IIII','IIII'/
C
C   READ CARDS WTA, WTB, WTC, WTD
C
      READ(IREAD,1000) WCARD(1),TITLEA,    WCARD(2),TITLEB,WCARD(3),
     1   TITLEC,    WCARD(4),STAID,SITID,NMON,NDAY,NYEAR
      NPAGE = NPAGE + 1
      WRITE(IPRNT,1050) APEC,NMON,NDAY,NYEAR,ESP,NPAGE
      WRITE(IPRNT,1040) ESP1
      WRITE(IPRNT,1030) TITLEA,TITLEB,TITLEC
      NPAGE = NPAGE + 1
      WRITE(IPRNT,1050) APEC,NMON,NDAY,NYEAR,ESP,NPAGE
C
C   CHECK CARD TYPE
C
      DO 140 I = 1,4
      IF (WCARD(I).EQ.CARDCK(I)) GO TO 140
      WRITE(IPRNT,1120) WCARD(I)
      IERR = 1
```

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      GO TO (100,110,120,130),I
  100 CONTINUE
      WRITE(IPRNT,1060) WCARD(I),TITLEA
      GO TO 140
  110 CONTINUE
      WRITE(IPRNT,1060) WCARD(I),TITLEB
      GO TO140
  120 CONTINUE
      WRITE(IPRNT,1060) WCARD(I),TITLEC
      GO TO 140
  130 CONTINUE
      WRITE(IPRNT,1070) WCARD(I),STAID,SITID,NMON,NDAY,NYEAR
C
  140 CONTINUE
       IF(IERR.NE.0) GO TO 400
C
C   READ WTE CARD
C
      READ(IREAD,1010) WCARD(5),NSTAT,NSITE,    ELSTAT,SLAT,SLON,ELSITE,
     1    NTZ,CNS,CNW,     JYEAR,NSCH,KDST,JDSTM
      LEAP = 0
      IF (MOD(JYEAR,4).EQ.0) LEAP = 1
      NDOY=365
      IF(LEAP.NE.0) NDOY=366
      KD=1
      IF(KDST.NE.0) KD=2
      WRITE(IPRNT,1080) NSTAT,STAID,ELSTAT,    NSITE,SITID,ELSITE,SLAT,
     1   SLON,NTZ,     CNS,CNW,JYEAR,(YRLEAP(I,LEAP+1),I=1,5),    (DSTKY(I,
     2     KD),I=1,6)
C
      IF (KDST.NE.0) WRITE(IPRNT,1090) JDSTM
C
C   CHECK STATION AND SITE PARAMETERS
C
      IF (WCARD(5).EQ.CARDCK(5)) GO TO 150
      WRITE(IPRNT,1120) WCARD(5)
      IERR = 1
C
  150 CONTINUE
      IF (NSTAT.GT.0) GO TO 160
      WRITE(IPRNT,1140) NSTAT
      IERR = 1
C
  160 CONTINUE
      IF (NSITE.GE.0) GO TO 170
      WRITE(IPRNT,1150) NSITE
      IERR = 1
C
  170 CONTINUE
      IF (ELSTAT.GE.0) GO TO 180
      WRITE(IPRNT,1160) ELSTAT
      IERR = 1
C
  180 CONTINUE
      IF (SLAT.GE.-90..AND.SLAT.LE.90.) GO TO 190
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```
      WRITE(IPRNT,1170) SLAT
      IERR = 1
C
  190 CONTINUE
      IF (SLON.GE.0..AND.SLON.LE.360.) GO TO 200
      WRITE(IPRNT,1180) SLON
      IERR = 1
C
  200 CONTINUE
      IF (ELSITE.GE.0.) GO TO 210
      WRITE(IPRNT,1190) ELSITE
      IERR = 1
C
  210 CONTINUE
      IF (NTZ.GE.0.AND.NTZ.LE.23) GO TO 220
      WRITE(IPRNT,1200) NTZ
      IERR = 1
C
  220 CONTINUE
      IF (CNS.GT.0.) GO TO 230
      WRITE(IPRNT,1210) CNS
      IERR = 1
C
  230 CONTINUE
      IF (CNW.GT.0.) GO TO 240
      WRITE(IPRNT,1220) CNW
      IERR = 1
C
  240 CONTINUE
      IF (JYEAR.GE.1948.AND.JYEAR.LE.2099) GO TO 250
      WRITE(IPRNT,1230) JYEAR
      IERR = 1
C
  250 CONTINUE
      IF (NSCH.GE.0.AND.NSCH.LE.20) GO TO 260
      WRITE(IPRNT,1240) NSCH
      IERR = 1
  260 CONTINUE
      IF (KDST.GE.0.AND.KDST.LE.1) GO TO 270
      WRITE(IPRNT,1320) KDST
      IERR = 1
C
  270 CONTINUE
      DO 280 I = 1,12
      IF (JDSTM(I).GE.0.AND.JDSTM(I).LE.1) GO TO 280
      WRITE(IPRNT,1330) JDSTM(I)
      IERR = 1
  280 CONTINUE
C
C     CHECK FOR PRINT SCHEDULES
C
      IF (IERR.NE.0) GO TO 400
      LPOPTC = -1
      IF (NSCH.EQ.0) GO TO 410
      IF (LEAP.NE.0) NDM(2) = 29
```

```
      LDAY = 0
      WRITE(IPRNT,1100) NSCH
C
C  READ WTF CARD - PRINT SCHEDULES
C
      DO 390 I = 1,NSCH
      READ(IREAD,1020) WCARD(6),ISCH,LMBEG(I),LDBEG(I),    LMEND(I),
     1  LDEND(I),LPOPT(I),(LPRSW(J,I),J=2,25)
      WRITE(IPRNT,1110) ISCH,LMBEG(I),LDBEG(I),LMEND(I),LDEND(I),
     1   (WOPT(J,LPOPT(I)+1),J=1,3),(LPRSW(J,I),J=2,25)
C
C  CHECK PRINT SCHEDULE PARAMETERS
C
      IF (WCARD(6).EQ.CARDCK(6)) GO TO 290
      WRITE(IPRNT,1120) WCARD(6)
      IERR = 1
C
  290 CONTINUE
      IF (ISCH.EQ.I) GO TO 300
      WRITE(IPRNT,1250) ISCH
      IERR = 1
C
  300 CONTINUE
      IF (LMBEG(I).LT.1.OR.LMBEG(I).GT.12) GOTO 310
      IF (LDBEG(I).GE.1.AND.LDBEG(I).LE.NDM(LMBEG(I))) GOTO 320
  310 CONTINUE
      WRITE(IPRNT,1260) LMBEG(I),LDBEG(I)
      IERR = 1
C
  320 CONTINUE
      IF (LMEND(I).LT.1.OR.LMEND(I).GT.12) GOTO 330
      IF (LDEND(I).GE.1.AND.LDEND(I).LE.NDM(LMEND(I))) GOTO 340
  330 CONTINUE
      WRITE(IPRNT,1270) LMEND(I),LDEND(I)
      IERR = 1
C
  340 CONTINUE
      IF (LPOPT(I).GE.0.AND.LPOPT(I).LE.1) GO TO 350
      WRITE(IPRNT,1280) LPOPT(I)
      IERR = 1
C
  350 CONTINUE
      LPOPT(I) = LPOPT(I) + 1
          DO 360 J = 2,25
          IF (LPRSW(J,I).GE.0.AND.LPRSW(J,I).LE.1) GO TO 360
          WRITE(IPRNT,1290) LPRSW(J,I)
          IERR = 1
  360     CONTINUE
C
      IF (IERR.NE.0) GO TO 400
      LBEG(I) = NDBM(LMBEG(I)) + LDBEG(I)
      IF (LEAP.NE.0 .AND. LMBEG(I).GT.2) LBEG(I) = LBEG(I) + 1
      IF (LBEG(I).GT.LDAY) GO TO 370
      WRITE(IPRNT,1300)
      IERR = 1
```

```
      GO TO 400
C
  370 CONTINUE
      LEND(I) = NDBM(LMEND(I)) + LDEND(I)
      IF(LEAP.NE.0.AND. LMEND(I).GT.2) LEND(I)=LEND(I)+1
      IF (LEND(I).GE.LBEG(I)) GO TO 380
      WRITE(IPRNT,1310)
      IERR = 1
      GO TO 400
  380 CONTINUE
      LDAY = LEND(I)
C
  390 CONTINUE
      LPOPTC = 0
      ISCH = 1
      NEXT = LBEG(ISCH)
      GO TO 410
C
  400 CONTINUE
      WRITE(IPRNT,1130)
C
  410 CONTINUE
      RETURN
C
C
C
 1000 FORMAT(3(A3,2X,10A4/),
     2   A3,2X,6A4,6A4,I2,I2,I2)
 1010 FORMAT(A3,2X,I5,I2,1X,F5.0,F5.2,F5.2,F5.0,
     2   I2,1X,F3.2,F3.2,1X,I4,1X,I2,I2,12I1)
 1020 FORMAT(A3,I2,1X,I2,1X,I2,1X,I2,1X,I2,1X,I1,1X,24I1)
 1030 FORMAT(15(/),(T19,10A4))
 1040 FORMAT(15(/),(T15,12A4))
 1050 FORMAT(1H1,14A4,10X,I2,1H/,I2,1H/,I2/1X,74(1H-)/
     2   1X,8A4,34X,4HPAGE,1X,I3/1X,74(1H*)/)
 1060 FORMAT(1X,A3,2X,10A4)
 1070 FORMAT(1X,A3,2X,6A4,6A4,I2,I2,I2,21X)
 1080 FORMAT(/33X,'INPUT DATA'/33X,'----- ----'///
     2   1X,'WEATHER STATION'/1X,'------- -------'/
     3   5X,'NO.  ',I5,'  -  ID-',6A4,/19X,'ELEVATION - ',F6.0,' FT'//
     4   1X,'SITE'/1X,'----'/5X,'NO.  ',I5,'  -  ID-',6A4/
     5   19X,'ELEVATION - ',F6.0,' FT'/
     6   19X,'LATITUDE  - ',F6.2,' DEGREES'/
     7   19X,'LONGITUDE - ',F6.2,' DEGREES'/
     8   19X,'TIME ZONE - ',I2//
     9   1X,'CLEARNESS NUMBERS'/1X,'--------- -------'/
     A   5X,'SUMMER - ',F4.2/5X,'WINTER - ',F4.2//
     B   1X,'WEATHER YEAR  -  ',I4,4X,5A4/
     C   1X,'------- ----'//
     D   1X,'DAYLIGHT SAVINGS TIME  -  ',6A4/
     E   1X,'-------- ------- ----')
 1090 FORMAT(1H+,36X,12I1//)
 1100 FORMAT(/1X,'HOURLY PRINT SCHEDULES  - ',I2/
     2   1X,'------ ----- ---------'/
     3   40X,'PRINT/NO PRINT SWITCH'/
```

```
     4   5X,'NO.  BEGIN   END   PRINT OPTION   ',
     5   '12345678901234567890l234'/)
1110 FORMAT(5X,I2,3X,I2,1H/,I2,2X,
     2   I2,1H/,I2,4X,3A4,1X,24I1)
1120 FORMAT(1X,'*** ERROR - INVALID CARD TYPE - ',A3)
1130 FORMAT(1X,'****** PROGRAM TERMINATED WITH INPUT ERRORS ******')
1140 FORMAT(1X,'*** ERROR - INVALID STATION NUMBER - ',I5)
1150 FORMAT(1X,'*** ERROR - INVALID SITE NUMBER - ',I2)
1160 FORMAT(1X,'*** ERROR - INVALID STATION ELEVATION - ',F8.2)
1170 FORMAT(1X,'*** ERROR - INVALID SITE LATITUDE - ',F6.2)
1180 FORMAT(1X,'*** ERROR - INVALID SITE LONGITUDE - ',F6.2)
1190 FORMAT(1X,'*** ERROR - INVALID SITE ELEVATION - ',F8.2)
1200 FORMAT(1X,'*** ERROR - INVALID TIME ZONE NUMBER - ',I2)
1210 FORMAT(1X,'*** ERROR - INVALID CLEARNESS NUMBER FOR SUMMER - ',
     2   F4.2)
1220 FORMAT(1X,'*** ERROR - INVALID CLEARNESS NUMBER FOR WINTER - ',
     2   F4.2)
1230 FORMAT(1X,'*** ERROR - INVALID WEATHER YEAR - ',I4)
1240 FORMAT(1X,'*** ERROR - INVALID NUMBER OF PRINT SCHEDULES - ',I2)
1250 FORMAT(1X,'*** ERROR - PRINT SCHEDULE IS INVALID ',
     2   'OR OUT OF SEQUENCE')
1260 FORMAT(1X,'*** ERROR - INVALID BEGINNING DATE - ',I2,'/',I2)
1270 FORMAT(1X,'*** ERROR - INVALID ENDING DATE - ',I2,'/',I2)
1280 FORMAT(1X,'*** ERROR - INVALID PRINT OPTION - ',I1)
1290 FORMAT(1X,'*** ERROR - INVALID PRINT / NO PRINT SWITCH - ',I1)
1300 FORMAT(1X,'*** ERROR - BEGINNING DATE OUT OF SEQUENCE')
1310 FORMAT(1X,'*** ERROR - ENDING DATE OUT OF SEQUENCE')
1320 FORMAT(1X,'*** ERROR - INVALID DAYLIGHT SAVINGS SWITCH- ',
     2   I1)
1330 FORMAT(1X,'*** ERROR - INVALID DAYLIGHT SAVINGS TIME FLAG - ',I1)
      END
      SUBROUTINE INIT
C
C    A SUBROUTINE WHICH READS DATA FROM THE TRY WEATHER
C    TAPE FOR THE FIRST DAY OF THE YEAR AND VERIFIES
C    THAT IT MATCHES THE USER'S SPECIFICATIONS.  INITIALIZATION
C    FOR VALIDITY CHECKING, PSYCHROMETRIC CALCULATIONS,
C    AND SOLAR CALCULATIONS IS PERFORMED.
C
      DIMENSION NDB(12)
      DIMENSION PRM(48,14)
      EQUIVALENCE(PRM(1,1),TOA(1))
      COMMON /INPOUT/
     1   IREAD,IPRNT,ITRY,ISWF,IERR,TITLEA(10),TITLEB(10),
     2   TITLEC(10),APEC(14),ESP(8),NMON,NDAY,NYEAR,NPAGE
C
      COMMON /HDRPRM/
     1   NSTAT,NSITE,JYEAR,LEAP,ELSTAT,SLAT,SLON,ELSITE,
     2   NTZ,CNS,CNW,STAID(6),SITID(6)
C
      COMMON /DAILYP/
     1   KDST,JDSTM(12),NSCH,ISCH,NEXT,NDPP,LDPP,LPR(25),LPOPTC,
     2   LMBEG(20),LDBEG(20),LMEND(20),LDEND(20),
     3   LPOPT(20),LPRSW(25,20),LBEG(20),LEND(20),
     4   NDOY,JDOY,JMON,JDOM,JDOW,JDST,JHOL,KMON,KDOM
```

```
C
      COMMON /WTHPRM/
     1   PC1,PC2,PC3,PBSTAT,PBSITE,RPB,FA(6),FB(6),FC(6),
     2   CPMON(12),CQMON(12),CRMON(12),CP,CQ,CR,
     3   BND1(14),BND2(14),DPARM(14),DIG(14),ITOPT(14),NMISS(14),
     4   ISW(48,14),TOA(48),TWB(48),PATM(48),
     5   WDIRD(48),WVELK(48),TCA(48),CA(48,4),TOC(48,4),
     6   TDP(25),WOA(25),HOA(25),DOA(25),WDIRR(25),WVELM(25),FO(6,25)
C
      COMMON /SOLRAD/
     1   A0(9),A1(9),A2(9),A3(9),B1(9),B2(9),B3(9),
     2   TSD,SET,SA,SB,SC,TZN12,CNMON(12),CN,CN2I,
     3   SLATR,SSLAT,CSLAT,TSLAT,SLONR,
     4   ISUN(25),COSW(25),COSS(25),COSZ(25),
     5   CC(25),CCF(25),RDRHC(25),RDFHC(25),FDIFF(25)
C
C
      DATA NDB/0,31,59,90,120,151,181,212,243,273,304,334/
C
C   READ NEXT TRY TAPE RECORD
C
      K1 = 1
  100 CONTINUE
      READ(ITRY,1000) KSTAT,TOA(25),TWB(25),    WDIRD(25),WVELK(25),
     1 PATM(25),    TCA(25),(CA(25,J),TOC(25,J),J=1,4),    KYEAR,KMON,
     2 KDOM,KHOD
C
C   CHECK FOR CORRECT STATION AND YEAR
C
      IF (KSTAT.EQ.NSTAT .AND.  KYEAR.EQ.JYEAR) GO TO 120
      L = 0
      IF(MOD(KYEAR,4).EQ.0) L = 24
      NSKIP = 8759+L
      IF(K1.EQ.0) GOTO 110
      K1 = 0
      NSKIP = NSKIP-24*(NDB(KMON)+KDOM-1)-KHOD
      NPAGE = NPAGE+1
      WRITE(IPRNT,1030) APEC,NMON,NDAY,NYEAR,ESP,NPAGE
  110 CONTINUE
      WRITE(IPRNT,1040) KSTAT,KYEAR
      READ(ITRY,1020) (KSTAT, I=1,NSKIP)
      GOTO 100
C
C   CHECK FOR CORRECT STARTING TIME - JAN. 1, HOUR 0
C
  120 CONTINUE
      IF (KMON.EQ.1.AND.KDOM.EQ.1.AND.KHOD.EQ.0) GO TO 140
C
C   INCORRECT STARTING TIME
C
      IF(K1.EQ.0) GOTO 130
      NPAGE = NPAGE+1
      WRITE(IPRNT,1030) APEC,NMON,NDAY,NYEAR,ESP,NPAGE
  130 CONTINUE
      WRITE(IPRNT,1050) KSTAT,KYEAR,KMON,KDOM,KHOD
```

```
      IERR = 1
      GO TO 230
C
C   READ PARAMETERS FOR REMAINDER OF FIRST DAY
C
 140 CONTINUE
      READ(ITRY,1010) (TOA(I),TWB(I),WDIRD(I),WVELK(I),    PATM(I),TCA(I)
     1     ,(CA(I,J),TOC(I,J),J=1,4),I=26,48)
C
C   WRITE HEADER RECORD ON SITE WEATHER FILE
C
C
C   INITIALIZE FOR INTERPOLATION
C
      IT = 1
      BD1 = BND1(7)
      BD2 = BND2(7)
      BD3 = BND2(11) + 1.
      DO 170 JP = 1,14
      NMISS(JP) = 0
        DO 160 IHOD = 25,48
          DO 150 J = 1,4
          IF (CA(IHOD,J).LT.BD1.OR.           CA(IHOD,J).GT.BD2)
     1    TOC(IHOD,J) = BD3
 150      CONTINUE
        ISW(IHOD,JP) = 0
 160    CONTINUE
      CALL VALCHK(IT,PRM(1,JP),BND1(JP),BND2(JP),    DPARM(JP),DIG(JP),
     1    NMISS(JP),ISW(1,JP))
 170 CONTINUE
C
C   INITIALIZE DAY OF WEEK AND DAYLIGHT SAVINGS TIME
C
      NYR = MOD(JYEAR - 1900,28)
      NDA = NYR + ((NYR + 3) / 4) + 6
      JDOW = MOD(NDA,7) + 1
      JDST = 0
C
C   INITIALIZE FOR BAROMETRIC ADJUSTMENT
C
      RPB = 1.
      IF (ABS(ELSITE - ELSTAT).LT.100.) GO TO 180
      PBSTAT = (PC1 * (ELSTAT**2)) + (PC2 * ELSTAT) + PC3
      PBSITE = (PC1 * (ELSITE**2)) + (PC2 * ELSITE) + PC3
      RPB = PBSITE / PBSTAT
 180 CONTINUE
C
C   CONVERT LATITUDE AND LONGITUDE FROM DEGREES TO RADIANS
C
      SLATR = .0174533 * SLAT
      SSLAT = SIN(SLATR)
      CSLAT = COS(SLATR)
      TSLAT = TAN(SLATR)
      SLONR = .0174533 * SLON
      TZN12 = NTZ - 12
```

```
C
C   SELECT FOURIER COEFFICIENTS FOR CALCULATING SOLAR PARAMETERS -
C   COEFFICIENTS DIFFER FOR NORTHERN AND SOUTHERN HEMISPHERES
C
      IBC = 5
      IF (SLAT.LT.0.) IBC = 7
      DO 190 I = 4,5
      IBC = IBC + 1
      A0(I) = A0(IBC)
      A1(I) = A1(IBC)
      A2(I) = A2(IBC)
      A3(I) = A3(IBC)
      B1(I) = B1(IBC)
      B2(I) = B2(IBC)
      B3(I) = B3(IBC)
  190 CONTINUE
C
C   DETERMINE MONTHLY VALUES OF CLEARNESS NUMBERS
C
      DO 200 M = 1,4
      CNMON(M) = CNW
  200 CONTINUE
       DO 210 M=5,10
      CNMON(M) = CNS
  210 CONTINUE
      DO 220 M = 11,12
      CNMON(M) = CNW
  220 CONTINUE
C
C   RETURN TO CALLER
C
  230 CONTINUE
      RETURN
C
C
 1000 FORMAT(I5,2F3.0,3X,2F3.0,F4.2,1X,F2.0,F2.0,F1.0,
     2   3X,3(F2.0,F1.0,5X),12X,I4,3I2)
 1010 FORMAT((5X,2F3.0,3X,2F3.0,F4.2,1X,F2.0,F2.0,F1.0,
     2   3X,3(F2.0,F1.0,5X)))
 1020 FORMAT(I5)
 1030 FORMAT(1H1,14A4,10X,I2,1H/,I2,1H/,I2 / 1X,74(1H-) /
     2   1X,8A4,34X,4HPAGE,1X,I3 / 1X,74(1H*) /)
 1040 FORMAT(/T2,'*** TRY TAPE - STATION ',I5,'  YEAR ',I4,
     2   ' - BYPASSED ***')
 1050 FORMAT(//T2,'*** ERROR - DATA FOR  STATION ',I5,'  YEAR ',I4 /
     2   T14,'DOES NOT START AT BEGINNING OF YEAR' //
     3   T20,'MONTH = ',I2 / T20,'DAY   = ',I2 / T20,'HOUR  = ',I2)
      END
C
C
C
C
      SUBROUTINE OUTDAY
C
C   A SUBROUTINE WHICH OUTPUTS A DAY RECORD TO THE
```

```
C   SITE WEATHER FILE AND OPTIONALLY PRINTS HOURLY
C   PARAMETERS.
C
      DIMENSION IHOUR(25),YMONTH(12),YDAY(3,7),
     2   YTIME(6,2),YHOLID(3,2),SWA(2),SW(7)
        DIMENSION ITOA(48),IVELM(48),IDRHC(48),IDFHC(48)
      COMMON /INPOUT/
     1   IREAD,IPRNT,ITRY,ISWF,IERR,
     2   TITLE(30),APEC(14),ESP(8),NMON,NDAY,NYEAR,NPAGE
      COMMON /HDRPRM/
     1   NSTAT,NSITE,JYEAR,LEAP,ELSTAT,SLAT,SLON,ELSITE,
     2   NTZ,CNS,CNW,STAID(6),SITID(6)
      COMMON /DAILYP/
     1   KDST,JDSTM(12),NSCH,ISCH,NEXT,NDPP,LDPP,LPR(25),LPOPTC,
     2   LMBEG(20),LDBEG(20),LMEND(20),LDEND(20),
     3   LPOPT(20),LPRSW(25,20),LBEG(20),LEND(20),
     4   NDOY,JDOY,JMON,JDOM,JDOW,JDST,JHOL,KMON,KDOM
      COMMON /WTHPRM/
     1   PC1,PC2,PC3,PBSTAT,PBSITE,RPB,FA(6),FB(6),FC(6),
     2   CPMON(12),CQMON(12),CRMON(12),CP,CQ,CR,
     3   BND1(14),BND2(14),DPARM(14),DIG(14),ITOPT(14),NMISS(14),
     4   ISW(48,14),TOA(48),TWB(48),PATM(48),
     5   WDIRD(48),WVELK(48),TCA(48),CA(48,4),TOC(48,4),
     6   TDP(25),WOA(25),HOA(25),DOA(25),WDIRR(25),WVELM(25),FO(6,25)
      COMMON /SOLRAD/
     1   A0(9),A1(9),A2(9),A3(9),B1(9),B2(9),B3(9),
     2   TSD,SET,SA,SB,SC,TZN12,CNMON(12),CN,CN2I,
     3   SLATR,SSLAT,CSLAT,TSLAT,SLONR,
     4   ISUN(25),COSW(25),COSS(25),COSZ(25),
     5   CC(25),CCF(25),RDRHC(25),RDFHC(25),FDIFF(25)
C
      DATA IHOUR/0,1,2,3,4,5,6,7,8,9,10,11,12,13,
     2   14,15,16,17,18,19,20,21,22,23,24/,IDUM/0/,
     3   YMONTH/'JAN','FEB','MAR','APR','MAY',
     4   'JUN','JUL','AUG','SEP','OCT','NOV','DEC'/,
     5   YDAY/'SUND','AY  ','    ','MOND','AY  ','    ',
     6   'TUES','DAY ','    ','WEDN','ESDA','Y   ',
     7   'THUR','SDAY','    ','FRID','AY  ','    ',
     8   'SATU','RDAY','    '/
      DATA YTIME/'STAN','DARD',' TIM','E   ','    ','    ',
     2   'DAYL','IGHT',' SAV','INGS',' TIM','E   '/,
     3   YHOLID/'    ','    ','    ',
     4   '*HOL','IDAY','*   '/,SWA/'    ','*   '/
C
C   OUTPUT DAY RECORD TO SITE WEATHER FILE
        IIYER= MOD(JYEAR,100)
C
        IIDAT=JMON*10000+JDOM*100+IIYER
        DO 12 I=2,25
        ITOA(I)=TOA(I)
        IVELM(I)=WVELM(I)
        IDRHC(I)=RDRHC(I)
        IDFHC(I)=RDFHC(I)
   12 CONTINUE
C
```

```
      WRITE(ISWF,1001) IIDAT,(ITOA(I),I=2,25)
      WRITE(ISWF,1001) IIDAT,(IVELM(I),I=2,25)
      WRITE(ISWF,1001) IIDAT,(IDRHC(I),I=2,25)
      WRITE(ISWF,1001) IIDAT,(IDFHC(I),I=2,25)
C
C   OPTIONAL PRINT
C
C  CHECK CURRENT PRINT OPTION
C
      IF (LPOPTC)230,110,100
C
C   CURRENTLY PRINTING - CHECK FOR ENDING DATE
C
  100 CONTINUE
      IF (JDOY.NE.NEXT) GO TO 130
      IF (ISCH.GE.NSCH) GO TO 220
      ISCH = ISCH + 1
      NEXT = LBEG(ISCH)
      LPOPTC = 0
C
C   CURRENTLY NOT PRINTING - CHECK FOR NEXT BEGIN DATE
C
  110 CONTINUE
C
      IF (JDOY.NE.NEXT) GO TO 230
      NEXT = LEND(ISCH) + 1
C
C   INITIALIZE FOR NEW PRINT SCHEDULE
C
      LPOPTC = LPOPT(ISCH)
      LPNH = 0
      DO 120 I = 2,25
      LPR(I) = LPRSW(I,ISCH)
      IF (LPR(I).NE.0) LPNH = LPNH + 1
  120 CONTINUE
      NDPP = 55 / (5 + (LPOPTC * LPNH))
      LDPP = 99
C
C   SKIP TO NEXT PAGE IF NECESSARY
C
  130 CONTINUE
      LDPP = LDPP + 1
      IF (LDPP.LE.NDPP) GO TO 140
      NPAGE = NPAGE + 1
      WRITE(IPRNT,1000) APEC,NMON,NDAY,NYEAR,ESP,NPAGE
      LDPP = 1
C
C   WRITE DAY PARAMETERS
C
  140 CONTINUE
      WRITE(IPRNT,1010) JDOY,JDOM,YMONTH(JMON),JYEAR,    (YDAY(I,JDOW),I=
     1  1,3),(YTIME(I,JDST+1),I=1,6),    (YHOLID(I,JHOL+1),I=1,3)
      IF (LPOPTC.EQ.2) GO TO 170
C
C   HOURLY OUTPUT - MAJOR PARAMETERS
```

```
C
      WRITE(IPRNT,1020)
      DO 160 IH = 2,25
      IF (LPR(IH).EQ.0) GOTO 160
      DO 150 J = 1,5
      SW(J) = SWA(ISW(IH,J)+1)
  150 CONTINUE
      WRITE(IPRNT,1030) IHOUR(IH),TOA(IH),WVELM(IH),RDRHC(IH),RDFHC(IH)
  160 CONTINUE
C
      GO TO 230
C
C   HOURLY OUTPUT - ALL PARAMETERS
C
  170 CONTINUE
      WRITE(IPRNT,1040)
      DO 210 IH = 2,25
      IF (LPR(IH).EQ.0) GOTO 210
      DO 180 J = 1,6
      SW(J) = SWA(ISW(IH,J)+1)
  180 CONTINUE
      SW(7) = SWA(2)
      DO 190 J = 7,14
      IF(ISW(IH,J).NE.0) GOTO 200
  190 CONTINUE
      SW(7) = SWA(1)
  200 CONTINUE
      WRITE(IPRNT,1050)   IHOUR(IH),TOA(IH),SW(1),TWB(IH),SW(2),TDP(IH),
     1    PATM(IH),SW(3),    WOA(IH),HOA(IH),DOA(IH),WDIRD(IH),SW(4),
     2  WDIRR(IH),     (FO(I,IH),I=1,3),ISUN(IH),COSW(IH),COSS(IH),
     3  COSZ(IH),  RDRHC(IH),RDFHC(IH),FDIFF(IH),  WVELK(IH),SW(5),
     4  WVELM(IH),(FO(I,IH),I=4,6),    TCA(IH),SW(6),CC(IH),SW(7),CCF(IH)
  210 CONTINUE
C
      GO TO 230
C
C   SET SWITCH TO INDICATE NO MORE OUTPUT
C
  220 CONTINUE
      LPOPTC = -1
C
  230 CONTINUE
      RETURN
C
C
C
 1000 FORMAT(1H1,14A4,10X,I2,1H/,I2,1H/,I2/1X,74(1H-)/
     2   1X,8A4,34X,4HPAGE,1X,I3/1X,74(1H*)/)
 1001 FORMAT(1X,I6,24I3)
 1010 FORMAT(/1X,'DAY-',I3,3X,I2,1X,A3,1X,I4,3X,3A4,6A4,3A4/)
 1020 FORMAT(1X,'HOUR DRY-BULB ',
     2   '-WIND--MPH  DIR-RADIATION-DIF'/)
 1030 FORMAT(1X,I2,4X,F4.0,4X,F6.2,3X,F6.2,8X,F6.2)
 1040 FORMAT(1X,'HR  TOA  TWB  TDP  PATM   WOA   HOA   DOA  ',
     2   'WDIRD / WVELK  1/4 FO 2/5 FO 3/6 ISUN ',
```

```
     3   'CW/TCA CS/CC CZ/CCF  RDRHC  RDFHC FDIFF'/)
1050 FORMAT(1X,I2,1X,F4.0,A1,F4.0,A1,F4.0,1X,F5.2,A1,
     2   F6.5,1X,F5.2,1X,F5.4,1X,F4.0,A1,1X,F5.3,'RAD',1X,
     3   F5.2,1X,F5.2,1X,F5.2,2X,I1,2X,
     4   F5.2,2X,F5.2,2X,F4.2,3X,F6.2,1X,F6.2,1X,F5.3/
     5   44X,F4.0,A1,1X,F5.1,'MPH',2X,
     6   F5.2,1X,F5.2,1X,F5.2,7X,F3.0,A1,2X,F4.1,A1,1X,F5.3)
      END
C
C
C
C
        SUBROUTINE PSY1 (DB,WB,PB,DP,PV,W,H,V)
C
C   A SUBROUTINE WHICH CALCULATES
C              DEW POINT TEMPERATURE   DP
C              VAPOR PRESSURE          PV
C              HUMIDITY RATIO          W
C              ENTHALPY                H
C              VOLUME                  V
C   WHEN THE FOLLOWING ARE GIVEN
C              DRY BULB TEMPERATURE    DB
C              WET BULB TEMPERATURE    WB
C              BAROMETRIC PRESSURE     PB
C
  80 CONTINUE
     PVP=PVSF(WB)
     IF (DB-WB) 120,120,100
 100 WSTAR=0.622*PVP/(PB-PVP)
     IF (WB-32.) 110,110,130
 110 PV=PVP-5.704E-4*PB*(DB-WB)/1.8
     IF (PV .GT. 0.) GOTO 140
     WB = WB + 1.
     GOTO 80
C
 120 PV=PVP
     GO TO 140
C
 130 CDB=(DB-32.)/1.8
     CWB=(WB-32.)/1.8
     HL=597.31+0.4409*CDB-CWB
     CH=0.2402+0.4409*WSTAR
     EX=(WSTAR-CH*(CDB-CWB)/HL)/0.622
     PV=PB*EX/(1.+EX)
 140 W=0.622*PV/(PB-PV)
     V=0.754*(DB+459.7)*(1+7000*W/4360)/PB
     H=0.24*DB+(1061+0.444*DB)*W
     DP=DPF(PV)
     RETURN
C
     END
      FUNCTION PVSF (X)
C
C   A SUBROUTINE WHICH CALCULATES
C              VAPOR PRESSURE   PVSF
```

```
C   WHEN GIVEN
C             TEMPERATURE       X
C
      DIMENSION A(6),B(4),P(4)
      DATA A/-7.90298,5.02808,-1.3816E-7,11.344,8.1328E-3,-3.49149/,
     2   B/-9.09718,-3.56654,0.876793,0.0060273/
C
      T=(X+459.688)/1.8
      IF (T.LT.273.16) GO TO 100
C
      Z=373.16/T
      P(1)=A(1)*(Z-1)
      P(2)=A(2)*ALOG10(Z)
      Z1=A(4)*(1-1/Z)
      P(3)=A(3)*(10**Z1-1)
      Z1=A(6)*(Z-1)
      P(4)=A(5)*(10**Z1-1)
      GO TO 110
C
  100 Z=273.16/T
      P(1)=B(1)*(Z-1)
      P(2)=B(2)*ALOG10(Z)
      P(3)=B(3)*(1-1/Z)
      P(4)=ALOG10(B(4))
C
  110 SUM=0
      DO 120 I=1,4
  120 SUM=SUM+P(I)
      PVSF=29.921*10**SUM
C
      RETURN
      END
         SUBROUTINE SOLAR
C
C   A SUBROUTINE WHICH DETERMINES SOLAR POSITION AND
C   CALCULATES DIRECT AND DIFFUSE SOLAR RADIATION
C   FALLING ON A HORIZONTAL SURFACE UNDER A CLOUDY SKY
C   FOR EACH HOUR OF A DAY.
C
      DIMENSION DEABC(5)
      COMMON /DAILYP/
     1   KDST,JDSTM(12),NSCH,ISCH,NEXT,NDPP,LDPP,LPR(25),LPOPTC,
     2   LMBEG(20),LDBEG(20),LMEND(20),LDEND(20),
     3   LPOPT(20),LPRSW(25,20),LBEG(20),LEND(20),
     4   NDOY,JDOY,JMON,JDOM,JDOW,JDST,JHOL,KMON,KDOM
      COMMON /WTHPRM/
     1   PC1,PC2,PC3,PBSTAT,PBSITE,RPB,FA(6),FB(6),FC(6),
     2   CPMON(12),CQMON(12),CRMON(12),CP,CQ,CR,
     3   BND1(14),BND2(14),DPARM(14),DIG(14),ITOPT(14),NMISS(14),
     4   ISW(48,14),TOA(48),TWB(48),PATM(48),
     5   WDIRD(48),WVELK(48),TCA(48),CA(48,4),TOC(48,4),
     6   TDP(25),WOA(25),HOA(25),DOA(25),WDIRR(25),WVELM(25),FO(6,25)
      COMMON /SOLRAD/
     1   A0(9),A1(9),A2(9),A3(9),B1(9),B2(9),B3(9),
     2   TSD,SET,SA,SB,SC,TZN12,CNMON(12),CN,CN2I,
```

```
     3   SLATR,SSLAT,CSLAT,TSLAT,SLONR,
     4   ISUN(25),COSW(25),COSS(25),COSZ(25),
     5   CC(25),CCF(25),RDRHC(25),RDFHC(25),FDIFF(25)
C
      EQUIVALENCE(DEABC(1),TSD)
C
C     DAILY SOLAR VARIABLES
C
      ARG = .0172142 * JDOY
      SARG = SIN(ARG)
      CARG = COS(ARG)
      SARG2 = 2. * SARG * CARG
      CARG2 = 2. * CARG * CARG - 1.
      SARG3 = (SARG2 * CARG) + (CARG2 * SARG)
      CARG3 = (CARG2 * CARG) - (SARG2 * SARG)
      DO 100 I = 1,5
      DEABC(I) = A0(I) + (A1(I) * CARG)
     2           + (A2(I) * CARG2) + ( A3(I) * CARG3)
     3           + (B1(I) * SARG) + (B2(I) * SARG2)
     4           + (B3(I) * SARG3)
  100 CONTINUE
C
C     TRIG FUNCTIONS OF DECLINATION ANGLE
C
      SD = ATAN(TSD)
      SSD = SIN(SD)
      CSD = COS(SD)
C
C     INTERMEDIATE QUANTITIES
C
      CLSD = CSLAT * SSD
      SLCD = SSLAT * CSD
      SLSD = SSLAT * SSD
      CLCD = CSLAT * CSD
      SACN = SA * CN
      SCCN2I = SC * CN2I
C
C     COSINE OF SUNRISE (OR SUNSET) HOUR ANGLE
C
      CHP = -(TSLAT * TSD)
C
C     INITIALIZATION FOR HOUR LOOP
C
      H = .261799 * (TZN12 + SET) - SLONR
      IRISE = 0
      ISET = 0
      DO 150 IHOD = 2,25
C
C     CHECK IF PAST SUNSET
C
      IF (ISET.NE.0) GO TO 110
C
C     HOUR ANGLE, RADIANS
C
      H = H + .261799
        CH=COS(H)
C
C     SUN UP/DOWN INDICATOR
C
      IF (CH.GT.CHP) GO TO 120
```

```
C
 110 CONTINUE
C
C   SUN IS DOWN
C
     ISUN(IHOD) = 0
     COSW(IHOD) = 0.
     COSS(IHOD) = 0.
     COSZ(IHOD) = 0.
     CC(IHOD) = 0.
     CCF(IHOD) = 0.
     ISET = IRISE
     GO TO 150
C
 120 CONTINUE
C
C   SUN IS UP
C
     ISUN(IHOD) = 1
     IRISE = 1
     SH = SIN(H)
C
C   CLOUD COVER FACTOR CALCULATIONS
C
     X = 0.
     DO 130 J = 1,4
     IF (TOC(IHOD,J) .GE. 8.) X = X + CA(IHOD,J)
 130 CONTINUE
     CC(IHOD) = TCA(IHOD) - (0.5 * X)
     CCF(IHOD) = CP + (CQ * CC(IHOD)) + (CR * (CC(IHOD)**2))
C
C   DIRECTION COSINES OF DIRECT SOLAR BEAM
C
     COSW(IHOD) = CSD* SH
     COSS(IHOD) = (SLCD * CH) - CLSD
     IF (SLATR.LT.0.) COSS(IHOD) = -COSS(IHOD)
     COSZ(IHOD) = SLSD + (CLCD * CH)
C
     IF (COSZ(IHOD).GE..005) GO TO 140
     RDRHC(IHOD) = 0.
     RDFHC(IHOD) = 0.
     FDIFF(IHOD) = 0.
     GO TO 150
C
C   INTENSITY OF DIRECT NORMAL SOLAR RADIATION FOR A
C   CLOUDLESS DAY.
C
 140 CONTINUE
     RDRN = SACN * EXP(-SB / COSZ(IHOD))
C
C   DIFFUSE SKY RADIATION FOR A CLOUDLESS CONDITION
C
     BS = SCCN2I * RDRN
C
C   TOTAL RADIATION ON A HORIZONTAL SURFACE FOR A
```

```
C   CLOUDLESS CONDITION
C
     RTH = (RDRN * COSZ(IHOD)) + BS
C
C   FRACTION OF TOTAL RADIATION WHICH IS DIFFUSE
C
     FDIFF(IHOD) = BS / RTH
C
C   DIRECT AND DIFFUSE RADIATION FALLING ON A
C   HORIZONTAL SURFACE UNDER A CLOUDY SKY
C
     Y = 0.309 - (0.137 * COSZ(IHOD)) + (0.394 * (COSZ(IHOD)**2))
     CK = (COSZ(IHOD) / (SC + COSZ(IHOD))) + ((CP - 1.) / (1. - Y))
     IF (CK.LT.0.) CK = 0.
     RDRHC(IHOD) = RTH * CK * (1. - (CC(IHOD) / 10.))
     RDFHC(IHOD) = (RTH * CCF(IHOD)) - RDRHC(IHOD)
150 CONTINUE
C
       RETURN
C
     END
       SUBROUTINE VALCHK(ITOPT,PRM,BND1,BND2,DPARM,DIG,NMISS,ISW)
C
C
C
C   A SUBROUTINE WHICH CHECKS THE VALIDITY OF A WEATHER PARAMETER
C   OVER A 24 HOUR PERIOD, REPLACING INVALID OR MISSING DATA
C   WITH INTERPOLATED VALUES.
C
     DIMENSION PRM(48),ISW(48)
C
C   CHECK INTERPOLATION OPTION
C
     GO TO (100,130,150,230),ITOPT
C
C   INITIALIZATION OPTION (ITOPT = 1)
C
100 CONTINUE
     DO 110 IHOD = 25,48
     IF (PRM(IHOD).LE.BND2.AND.   PRM(IHOD).GE.BND1) GO TO 120
110 CONTINUE
C
C   USE DEFAULT PARAMETER FOR FIRST HOUR
C
     PRM(25) = DPARM
     ISW(25) = 1
     NMISS = 1
     GO TO 260
C
C   VALID PARAMETER FOUND ON TAPE - USE FOR FIRST HOUR
C
120 CONTINUE
     IF (IHOD.EQ.25) GO TO 260
     PRM(25) = PRM(IHOD)
     ISW(25) = 1
```

```
      NMISS = 1
      GO TO 260
C
C   LAST VALID VALUE OPTION (ITOPT = 2)
C
  130 CONTINUE
      DO 140 IHOD = 2,25
      IF (PRM(IHOD).LE.BND2.AND.   PRM(IHOD).GE.BND1) GO TO 140
C
C   INVALID PARAMETER
C
      PRM(IHOD) = PRM(IHOD - 1)
      ISW(IHOD) = 1
      NMISS = NMISS + 1
  140 CONTINUE
      GO TO 260
C
C   INTERPOLATION OPTION (ITOPT = 3)
C
  150 CONTINUE
      IH1 = 2
  160 CONTINUE
      DO 170 IHOD = IH1,25
      IF (PRM(IHOD).GT.BND2.OR.   PRM(IHOD).LT.BND1) GO TO 180
  170 CONTINUE
      GO TO 260
C
C   INVALID PARAMETER - SEARCH FOR NEXT VALID VALUE
C
  180 CONTINUE
      ISW(IHOD) = 1
      NMISS = NMISS + 1
      IX1 = IHOD - 1
      VAL1 = PRM(IX1)
      IH1 = IHOD + 1
      IH2 = IHOD + 9
      DO 190 IX2 = IH1,IH2
      IF (PRM(IX2).LE.BND2.AND.   PRM(IX2).GE.BND1) GO TO 210
      ISW(IX2) = 1
      NMISS = NMISS + 1
  190 CONTINUE
C
C   NO VALID PARAMETER FOR 9 HOURS OR MORE
C
      DO 200 IX2 = IHOD,IH2
      PRM(IX2) = VAL1
  200 CONTINUE
      IH1 = IH2 + 1
      IF (IH1.LE.25) GO TO 160
      GO TO 260
C
C   VALID PARAMETER FOUND - INTERPOLATE
C
  210 CONTINUE
      DELTA = (PRM(IX2) - VAL1) / (IX2 - IX1)
```

```
      IH1 = IX1 + 1
      IH2 = IX2 - 1
      TPRM = VAL1
      DO 220 IHOD = IH1, IH2
      TPRM = TPRM + DELTA
      IPRM = (TPRM * DIG) + 0.5
      PRM(IHOD) = IPRM / DIG
  220 CONTINUE
      IH1 = IX2 + 1
      IF (IH1.LE.25) GO TO 160
      GOTO 260
C
C   LAST HOUR OF YEAR (ITOPT = 4)
C
  230 CONTINUE
      DO 240 IHOD = 1,24
      IF (PRM(25-IHOD).LE.BND2.AND.   PRM(25-IHOD).GE.BND1) GO TO 250
  240 CONTINUE
C
  250 CONTINUE
      PRM(25) = PRM(25-IHOD)
C
C   RETURN TO CALLER
C
  260 CONTINUE
      RETURN
C
      END
        SUBROUTINE WPSY
C
C   A SUBROUTINE WHICH CALCULATES THE HUMIDITY RATIO,
C   ENTHALPY, AND DENSITY OF AIR FOR EACH HOUR OF A DAY.
C   WHEN NECESSARY, THE BAROMETRIC PRESSURE AND DEW
C   POINT TEMPERATURE ARE ADJUSTED FOR SITE ELEVATION.
C   WIND SPEED AND DIRECTION ARE CONVERTED AND OUTSIDE
C   SURFACE HEAT TRANSFER(FILM) COEFFICIENTS ARE CALCULATED.
C
       COMMON /WTHPRM/
      1   PC1,PC2,PC3,PBSTAT,PBSITE,RPB,FA(6),FB(6),FC(6),
      2   CPMON(12),CQMON(12),CRMON(12),CP,CQ,CR,
      3   BND1(14),BND2(14),DPARM(14),DIG(14),ITOPT(14),NMISS(14),
      4   ISW(48,14),TOA(48),TWB(48),PATM(48),
      5   WDIRD(48),WVELK(48),TCA(48),CA(48,4),TOC(48,4),
      6   TDP(25),WOA(25),HOA(25),DOA(25),WDIRR(25),WVELM(25),FO(6,25)
C
       DO 110 IHOD = 2,25
C
C   ADJUST BAROMETRIC PRESSURE FOR SITE ELEVATION
C
       PATM(IHOD) = RPB * PATM(IHOD)
C
C   CALCULATE PSYCHROMETRIC PARAMETERS
C
       CALL PSY1(TOA(IHOD),TWB(IHOD),PATM(IHOD),   TDP(IHOD),PV,WOA(IHOD)
      1    ,HOA(IHOD),V)
```

```
      DOA(IHOD) = 1. / V
C
C   CONVERT WIND DIRECTION FROM DEGREES TO RADIANS
C
      WDIRR(IHOD) = 0.0174533 * WDIRD(IHOD)
C
C   CONVERT WIND SPEED FROM KNOTS TO MPH
C
      WV = 1.153 * WVELK(IHOD)
      WV2 = WV * WV
      WVELM(IHOD) = WV
C
C   CALCULATE OUTSIDE SUFACE HEAT TRANSFER(FILM) COEFFICIENTS
C
      DO 100 IS = 1,6
      FO(IS,IHOD) = (FA(IS) * WV2) + (FB(IS) * WV) + FC(IS)
  100 CONTINUE
C
  110 CONTINUE
C
      RETURN
C
      END
```

## VITA AUCTORIS

1954 Born Kalulushi,Zambia, 18th June.

1973 Completed secondary school education, Hillcrest Technical Secondary School, Livingstone, Zambia.

1979 Received Bachelor of Engineering Degree (Distinction) in Mechanical Engineering from the University of Zambia, Lusaka, Zambia.

1981 Currently a candidate for the Degree of Master of Applied Science in Mechanical Engineering at the University of Windsor, Windsor, Ontario, Canada.